AD-A007 313

LUBRICATING OIL BURN-OFF IN COAST GUARD POWER PLANTS

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Transportation Systems Center

Prepared for:

Coast Guard

February 1975

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Technical Report Documentation Page

1. Report No. CG-D-80-75	2. Government Accession No.	3. Recipient's Catalog No. AD/A-007313
4. Title and Subtitle LUBRICATING OIL BURN-OFF IN COAST GUARD POWER PLANTS		5. Report Date February 1975
		6. Performing Organization Code
7. Author(s) J. R. Hobbs and R. A. Walter		8. Performing Organization Report No. DOT-TSC-USCG-74-6
9. Performing Organization Name and Address U.S. Department of Transportation Transportation Systems Center Kendall Square Cambridge MA 02142		10. Work Unit No. (TRAIS) CG507/R5001
		11. Contract or Grant No. TASK No. 754305.3/4
12. Sponsoring Agency Name and Address U.S. Department of Transportation United States Coast Guard Office of Research and Development Washington DC 20590		13. Type of Report and Period Covered Feasibility Study July - September 1974
		14. Sponsoring Agency Code DOT-G-DET-IC
15. Supplementary Notes		

16. Abstract

The results of a feasibility study for the burn-off of waste oils in Coast Guard power plants are presented. Among the factors considered in this evaluation were: simplicity, cost, engine manufacturers recommendations, mixing ratios, engine emissions, and effects on engine performance. As a result of this study it is recommended that waste oil be treated by procedures outlined in this study, blended at a mix ratio of 1% or less waste oil to diesel fuel oil, and burned off in Coast Guard power plants.

17. Key Words Lubricating Oil, Engine Performance, Diesel Engine, Emissions, Waste Oil, Disposal, Filters		18. Distribution Statement DOCUMENT IS AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 97	22. Price 75

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

PREFACE

Current waste lube oil disposal procedures of the Coast Guard are costly and inconvenient. For these reasons the Coast Guard is investigating shipboard procedures for the disposal of waste lube oil by burn-off in Coast Guard engines. This report documents the results of a background study to develop procedures for the adoption of such a program in the Coast Guard.

This study is based on information from engine manufacturers, lube oil and fuel oil filter manufacturers, bilge water separator manufacturers, emissions testing laboratories, fuel and lubrications manufacturers, government agencies, and industries concerned with waste oil disposal. Information was also solicited from cognizant Coast Guard personnel including headquarters, district and shipboard engineering staff. Efforts were directed primarily to burn-off of waste lube oil from diesel engines; however, recommendations regarding treatment and mixing are applicable to other waste oil products, including those from running gear and bilge.

The analysis described in this report was carried out by the Environmental Measurements Branch, DOT/Transportation Systems Center under the auspices of the United States Coast Guard, Office of Research and Development, Pollution Projects Branch, Cdr. D. Flannigan, Chief, and Mr. William McKay, Project Officer.

Grateful acknowledgement is made for the assistance of the following people, whose co-operation in providing information made this study possible:

H.R. Hartman, Turbo Power and Marine Systems, United Aircraft Corporation

J.G. Brandes, Detroit Diesel Allison, General Motors Corp.

L.L. Fowler, Vice-President, Cata-Sep Corp.

C.D. Shrake, Cummins Engine Company, Inc.

J. McGowan, Alco Engine Division, White Industrial Power Co.

D.L. Siekkinen,	Cooper-Bessemer Co.
W. Marshall,	Bureau of Mines, United States Department of the Interior
T. Sheehan,	Lubrizol, Inc.
Dr. J. Hickey,	Gas Turbine Product Division, General Electric Co.
Dr. A. Dreisen,	Engine Division, Allis-Chalmers
J. Gotleib,	International Harvester Co.
M. Grant,	Navy Petroleum Office
C. Gilbert,	Sun Oil Co.
W. J. Miller,	Babcock and Wilcox, Power Generation Group
M. Whisman,	Bureau of Mines, United States Department of the Interior
C. Newton,	Power Systems Division, Colt Industries
W. McEnary,	Caterpillar Tractor Co.
Capt. R. Lucas,	Chief, Naval Engineering, United States Coast Guard Headquarters
Lt. Cdr. L. Norton,	Naval Engineering Division, United States Coast Guard Headquarters
R.M. Carter,	Chief, Technical Section, Operations Division, First Coast Guard District
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1. INTRODUCTION

In FY73, the Coast Guard used 41,000,000 gal of fuel oil and 400,000 gal of lube oil.[1] It has not been determined at this time how much of the total lube oil ends up as recoverable waste oil and how much is lost by engine consumption. It is obvious, however, that in the Coast Guard fleet as a whole, the ratio of lube oil to fuel oil is less than 1%. Results on an individual class basis will be considered in section 5.3.

Waste lube oil generated by Coast Guard cutters is currently disposed of in several ways. On large Coast Guard vessels, most of the waste lube oil is stored in the dirty oil tank and then trucked away at a cost of ~13¢/gal. In smaller vessels and at port facilities the oil is stored in barrels and then hauled away. Some of this waste lube oil finds its way back into the environment either via direct or accidental discharge at sea or by bilge pumping. The fact that most of the waste lube oil is carried away by commerical concerns does not prevent a portion of this oil from entering the environment. Some of this waste lube oil is re-refined, some is used as fuel in land-based boilers and incinerators, some is used to coat dirt roads, and quantities are dumped into the environment.

Some of the waste lube oil from automobiles and heavy equipment is collected, re-refined, and sold as re-refined oil. This procedure cannot be utilized by the Coast Guard, since the fleet is widely distributed about the United States and the logistics and economics of collection and re-refining would not be warranted. In addition, the use of re-refined oils is not generally recommended by the engine manufacturers because of the inconsistency in the lubrication properties of different batches of re-refined oil. In some cases the use of this oil would void engine warranties.

Because of the environmental effects of the present disposal methods and the cost to the Coast Guard for removal of waste oil, an economical shipboard and base procedure is desirable for the

burn-off of waste lube oil. The main requirements of a shipboard and base waste lube oil burn-off program are:

(1) Sufficient treatment to preclude any detrimental effects to engine performance.

(2) No appreciable increase in engine emissions.

(3) A minimum of additional equipment and cost.

(4) Minimal maintenance for such equipment.

(5) Minimal operation time.

(6) Compatibility with existing equipment.

2. INFORMATION SEARCH

A literature search was conducted which included patents and literature on re-refining, disposal, analysis and uses of used oil. Publications of the Society of Automotive Engineers and the American Petroleum Institute were searched. Little information was found concerning burning waste lube oil in diesel engines. Specific information dealt with use of waste oil as incinerator and plant fuel. Some data on emissions from incinerators burning waste automotive oil came from these reports. In general, the literature search was non-productive in providing information pertinent to treatment and burn-off of waste lubricating oils in diesel engines. The literature surveyed is listed in Appendix A.

3. ENGINE MANUFACTURERS' RECOMMENDATIONS

The recommendations of the various diesel engine manufacturers were solicited regarding this task. Copies of letters received from the manufacturers of Coast Guard diesel engines appear in Appendix B.

Most of the engine manufacturers recommended a program of lube-oil burn-off in diesel engines, provided certain requirements are meet. All stressed proper treatment of the waste lube oil to minimize solids, water, and ash. The manufacturers recommended that this treated lube oil be mixed with fuel oil at a ratio of 1% to 5% by volume. In all cases, it was recommended that the mix ratio be maintained as low as possible, consistent with operational requirements.

It should be noted that these manufacturers' recommendations are based on a continuous burn-off program. In Coast Guard application,waste oil burning would occur on a non-routine basis as the need arose. Detroit Diesel was the only manufacturer not giving an unqualified go-ahead to a waste oil burn-off program. This reluctance is based on Detroit Diesel's own studies of ash build-up when burning higher ash content lubricating oil in the crankcase. A detailed discussion of Detroit Diesel's results are presented in Section 6. Detroit Diesel did agree that at a 1% mix ratio, and particularly on a non-continuous basis, the effect of the ash build-up would be minimal.

4. WASTE LUBE OIL BURN-OFF PROGRAMS

There are several diesel waste lube oil burn-off programs now in progress. The most thorough program was developed by Cummins Engine Co., Inc., for their diesel engines in the Coors Beer Company truck fleet. This program consists of filtering the drained diesel lube oil through four filters identical to spin-on diesel engine bypass filters except for a final Luber-Finer* filter. This filtered oil is mixed with fuel oil at a ratio of 3% by volume and burned in the Coors truck fleet. Coors has run these engines 100,000 miles with no adverse effects and has initiated the same procedure in a fleet of 70 Mercede Benz diesels. Since the Coors tests, Cummins Engine Company, Inc. has released a service bulletin on the use of treated 5% lube oil in No. 2 diesel fuel. Instructions and a parts list for the fabrication of a fuel filter-blender appear in Appendix C.

Kroger, Co., Cincinnati, Ohio, has also developed a lube oil burn-off program for its fleet of trucks equipped with Detroit Diesel 8V-71 engines. Four engines are operating on a 5% filtered lube oil/fuel oil mixture. The filtering system used is a specially designed Fram unit. Several engines have logged 100,000 miles and no problems have been encountered. There has been no increase in smoke, engine wear, or fuel consumption.

International Harvester Company has also issued a service bulletin for its diesel engine users which recommends filtering the waste lube oil through a funnel with a fine mesh screen. The filtered oil is added to the truck's fuel tanks, which are then filled with diesel fuel up to a maximum of 6-1/2% lube oil/fuel oil ratio.

*Trademark of Luber-Finer Inc., a Division of Rockwell International, Los Angeles, California.

The National Research Council of Canada and the Canadian National Railway undertook a program to determine the cost effectiveness of using 100% Canadian crude oil (high ash and high sulfur) as a fuel in GM 567C and 567D locomotive diesel engines. Several tests were run on a laboratory engine for 6,000 hours, followed by 6 months of field testing. The procedure was not adopted because the savings in fuel costs were offset by increased maintenance costs.

The U.S. Navy's waste oil program is one of collection and re-refining.[2] Some of the re-refined oil is used as lubricating oil in running gear and the remaining oil is burned off in shore boilers.

5. FUEL REQUIREMENTS

5.1 FUEL OIL AND LUBE OIL SPECIFICATIONS

Fuel oils and lube oils used in Coast Guard vessels are based on military fuel oil specifications MIL-F-16884F and lube oil specification MIL-L-9000G. The chemical and physical properties of these oils are shown in Tables 1 and 2 respectively. For consideration in a lube oil burn-off program, the important characteristics of diesel fuel affected by the addition of waste lube oil are: particulates, ash, sulfur, water, and carbon residue. Moreover, other characteristics of waste lube oil not normally found in diesel fuel oil should be considered, including metal wear products, soluble metal-containing additives (detergents and dispersants), and products of combustion and incomplete combustion of fuel oil. The detergents and dispersants are calcium salts and high-molecular-weight zinc amides which would contribute to the ash buildup during any combustion process.

Table 3 lists the various metals found in waste lubricating oils from gasoline engines, tabulated as to their source from wear, contamination, or additives.

Table 4 is a typical emission spectrographic analysis of lubricating oil in the #1 main diesel engine of the 378' WHEC Hamilton. Where possible, the source of the elements has been identified. It should be noted that the elements present in the oil at the highest levels (Ba, Ca, Zn and P) are additives. Although it is recognized that any cost-effective lube oil treatment method adopted by the Coast Guard will not completely eliminate these elements, especially the soluble metals, efforts should be directed towards minimizing them, since they may contribute to ash build-up in the engine.

5.2 TREATMENT SYSTEMS FOR WASTE LUBE OIL

In order to properly process waste lube oil, a treatment system should be capable of removing particulate contamination down to at least the 5 micron level and as much of the soluble

TABLE 1. CHEMICAL AND PHYSICAL PROPERTIES OF MIL-F-16884F, DIESEL FUEL OIL

Characteristic	Value
Ignition quality, cetane No. (min)	47
Appearance	Clear & Bright
Distillation:	
50 percent point, °F	record
90 percent point, °F (max.)	675
end point °F (max.)	725
Flash point, °F (min)	140
Cloud point, °F (max)	10
Pour point, °F (max)	0
Viscosity @ 100°F:	
Kinematic, centistokes	2.1-6.0
Saybolt Seconds Universal	33-45
Carbon residue, on 10 percent bottoms percent (max)	0.20
Sulfur, percent (max)	1.00
Corrosion (max) (at 212°F)	No. 1 ASTM
Color (max)	5
Ash, percent (max)	0.005
Gravity (Hydrometer)	record
Demulsification, minutes (max)	10
Acid No. (Max)	0.05
Neutrality	Neutral
Aniline point, °F	record
Accelerated Stability, total insolubles, mg/100 ml. (max)	2.5

TABLE 2. CHEMICAL & PHYSICAL PROPERTIES OF MIL-L-9000G, DIESEL LUBRICATING OIL

(Navy Symbol 9250.)

Characteristic	Value
Viscosity @ 210°F	
Centistokes	11.9-14.5 min.
Saybolt Sec., Universal	66-75
Flash Point °F, Min.	390
Pour Point, °F Max.	10
Ash, Sulfated, %	1.5-2.0 (3)
Contamination (mg/gal) Max.	10
Zinc	0.039% (3)
Phosphorous	0.036% (3)
Barium	- (3)
Calcium	0.49% (3)
Magnesium	- (3)
Chlorine	- (3)
Sulphur	0.22% (3)

TABLE 3. METALS FOUND IN WASTE AUTOMOTIVE LUBRICATING OIL[4]

Wear	Contamination	Additives
Fe	Si	P
Pb	Pb	Zn
Cu	B	B
Cr	Ca	Ca
Al	Al	Ba
Ni	Na	Na
Ag		Mg
Sn		

TABLE 4. EMISSION SPECTROGRAPHIC ANALYSIS OF LUBRICATING OIL FROM #1, MAIN DIESEL ENGINE, USCGC HAMILTON[5]

Element	Source	Amount (ppm)
Fe	Wear	18.9
Ti	Wear	2.9
Va	Wear	0.2
Pb	Wear	7.5
Cu	Wear	9.9
Sn	Wear	5.0
In	-	0.2
Sb	-	0.2
Cr	Wear	2.9
B	Contaminant	5.1
Na	Contaminant	41.1
Al	Wear	2.3
Si	Contaminant	5.7
Ag	Wear	0.2
Mo	-	1.3
Ba	Additive	329.7
Ca	Additive	102.2
Zn (High)	Additive	75.9
P	Additive	69.1
K	-	0.1
Cd	-	1.3
Ni	Wear	1.5
Mg	Contaminant	23.8
Mn	-	2.4
Co	-	0.2
Zn (Low)	Additive	111.2

and non-soluble contaminants as possible. Three alternate approaches for cleanup are available to the Coast Guard and will be discussed in detail below.

5.2.1 Bilge Water Separators

In the coming months all Coast Guard vessels over 65 feet in length will be equipped with bilge water separators. These separators are being installed to clean up bilge discharge water to acceptable EPA standards.

The units to be installed by the Coast Guard are manufactured by Separation and Recovery Systems, Inc., (SRS) and Cata-Sep Corp. Both of these units (Figure 1) consist of expendable pre-filters for removal of solids down to the 10 micron level and first and second stage oil/water separators containing expendable coalescer cartriges. The function of the first and second stage coalescer is to agglomerate the finely dispersed oil droplets into oil drops large enough to separate from the water phase by gravity. The oil thus separated accumulates at the top of the coalescer tank for subsequent removal. Generally, the first stage coalescer performs the oil/water separation adequately; however, the second stage coalescer is provided as a polishing stage and functions as a back-up in case of failure of the first stage unit. Both the first and second stage coalescers will remove and retain particulate matter down to the 1 micron level.

On any cutter over 100 ft, the discharge water from these units is monitored by a Fram oil/water analyzer to assure a maximum level of 20 ppm oil in the water. If this level is exceeded, the separator goes into recirculation until the discharge water is cleaned below the 20 ppm level.

The oil/water separators were designed to operate with 3% oil in the bilge water and were not intended to be used with 100% oil; however, it has been noted that the Cata Sep unit presently in use aboard the USCGC Hamilton (Figure 2) has the capability of removing water from fuel oil in the fuel oil tanks. Furthermore, the 10 gal/m and 100 gal/m units successfully separated a 90% diesel fuel

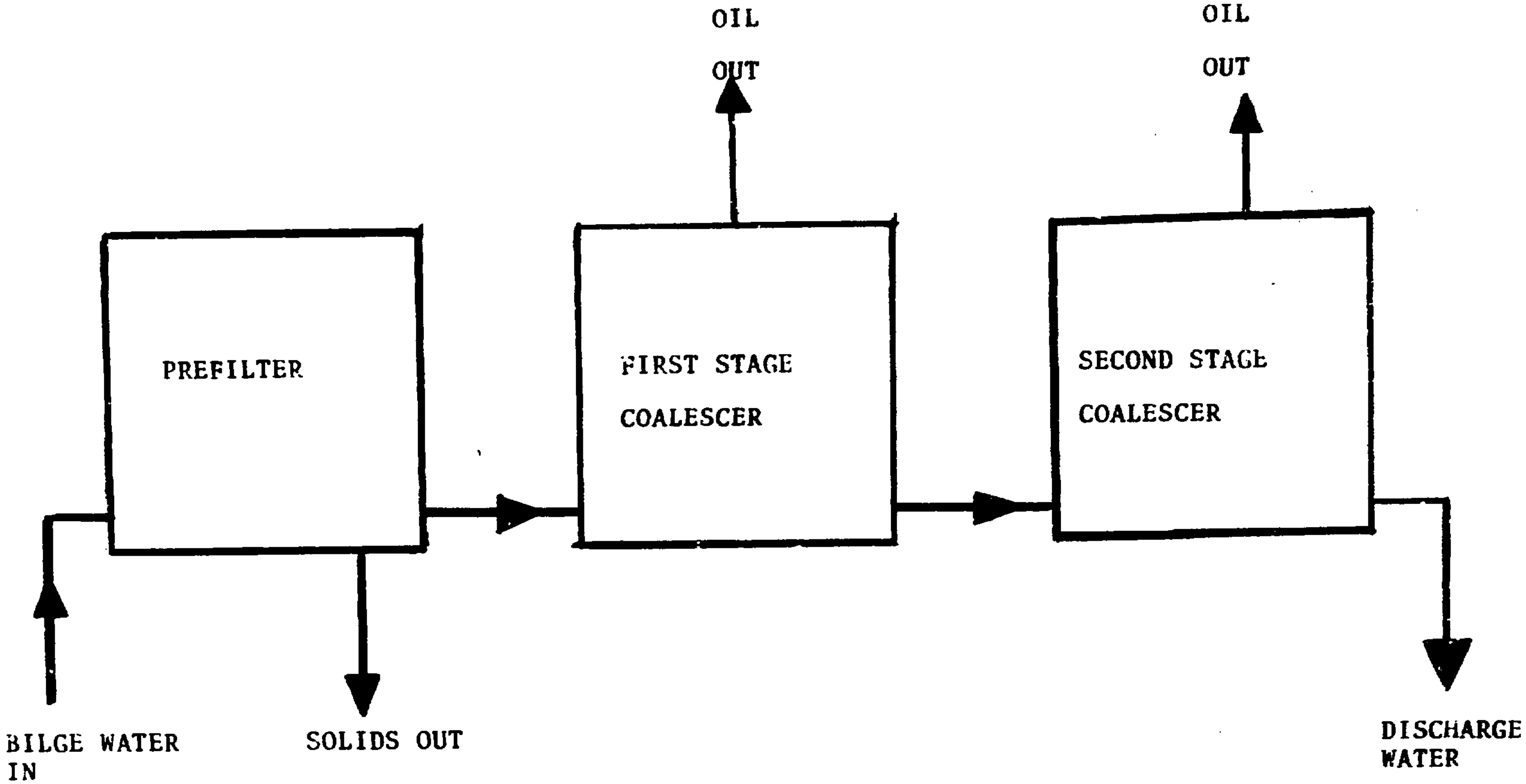

Figure 1. Typical Bilge Water Separator

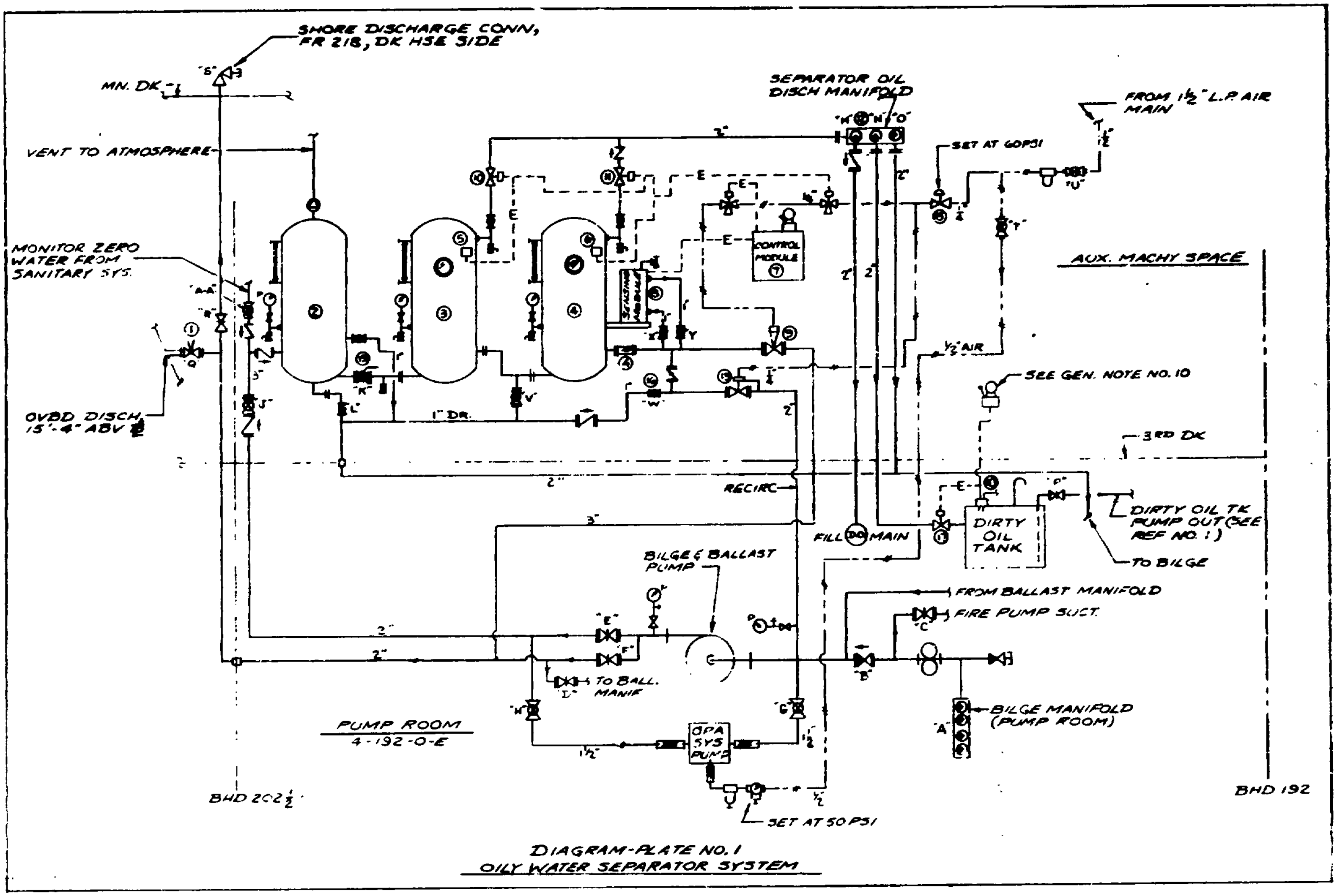

Figure 2. Plumbing Diagram - Bilge Water Separator as Installed on USCGC Hamilton

LEGEND

- GATE VALVE, FLANGED
- BALL VALVE, FLANGED
- CHECK VALVE
- SOLENOID VALVE
- BUTTERFLY VALVE, FLG'D
- GLOBE STOP CHECK
- VIEW PORT
- AIR ELIMINATOR
- SAMPLING COCK
- PRESS. REGULATING VALVE
- WAFER VALVE
- DIAPHRAM VALVE (AIR OPER.)
- LIQUID PIPING
- AIR PIPING
- ELECTRIC
- DUPLEX STRAINER
- FLOW INDICATOR
- FLANGE CONN.
- PRESS. GAUGE
- AUDIO ALARM
- AIR FILTER
- AIR REGULATOR

COMPONENT KEY

1. O.P.A SYSTEM OVBD DISCHARGE VALVE
2. O.P.A. SYSTEM PRE-FILTER
3. OILY WATER SEPARATOR "A"
4. OILY WATER SEPARATOR "B"
5. 1ST STAGE LEVEL CONTROL
6. 2ND STAGE LEVEL CONTROL
7. CONTROL MODULE
8. SENSING MODULE
9. WATER DISCHARGE VALVE
10. 1ST STAGE OIL OUTLET VALVE
11. 2ND STAGE OIL OUTLET VALVE
12. OIL DISCHARGE MANIFOLD
13. RECIRCULATING VALVE
14. EFFLUENT FLOW INDICATOR
15. O.P.A SYSTEM PRESS REGULATOR (AIR)
16. EFFLUENT DRAIN VALVE TO BILGE (NORMALLY CLOSED)
17. ELECTRICALLY OPERATED STOP VALVE
18. DIRTY OIL TANK LEVEL CONTROL
19. PREFILTER WATER OUTLET VALVE

MODES OF OPERATION

VALVE

MODE	A	B	C	D	E	F	G	H		J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
HIGH RATE DEWATERING	○	○	●	●	●	○	●	●		●	●	●	●	●	●	●	○	●	●	●	●	●	●	●	●	●
DEBALLASTING	●	●	●	●	○	●	●	●		○	○	●	○	●	●	●	○	●	●	●	●	●	●	○	○	○
ROUTINE BILGE PUMPING	○	○	●	●	●	●	○	○		○	○	●	●	○	●	●	○	●	●	○	○	●	●	○	○	○
REMOVE WATER FROM TK BOT.	●	●	●	●	●	●	○	○		○	○	●	○	●	●	●	○	●	●	○	○	●	●	○	○	○

○ - VALVE OPEN ● - VALVE CLOSED

FOR OILY WATER SEPARATOR SYSTEM DIAGRAM - PLATE NO 2

Figure 2. Plumbing Diagram - Bilge Water Separator as Installed on USCGC Hamilton (Cont'd)

with 10% water at rated flow for 3 minutes with the oil discharge containing no visible water and the water effluent discharge having no visible sheen.

A problem that could arise in using the bilge-water separator for treatment of waste lube oil would be premature plugging of the first stage coalescer filters. This could occur because the pre-filter will remove solids only down to the 10 micron level, thus passing many particulates to the first stage coalescer. Two alternate methods are available to alleviate this possible problem:

(1) An additional pre-filter with filtration ability to 5 microns or less could be added in the line between the waste lube oil source and the bilge water separator.

(2) The first stage pre-filter cartridge could be changed to a 5 or a 2 micron unit.

(3) The lube oil could be diluted 3 to 1 with fuel oil to improve filteration.

If necessary, both of these methods might be adopted to preclude the premature plugging of the first stage coalescer.

It should be emphasized that these measures may not be necessary, depending on the particulate loading in the waste lube oil. In the acceptance testing of the 100 gallon/minute Cata Sep unit, dirt (AC standard course dust) was injected into a 3% oil/water mixture at the rate of 1.25 ounces per minute. With the pre-filter removed, the first stage coalescer retained 155 ounces of dirt before the pressure differential had risen to 50 lb, a point at which an element change would be recommended by Cata Sep.

Taking a worst case possibility, if the main engines of a 378' WHEC were drained of lube oil, 680 gallons of oil would be available to run through the bilge water separator for treatment. Using the results of the acceptance test previously described, the particulate loading in this waste lube oil would have to be equivalent to 6.5 grams/gallon in order to raise the pressure differential to the 50 lb indicative of an element change.

In our estimation, 6.5 grams/gallon is an exceedingly high particulate contamination level to be found in lube oil. It should also be stressed again that the acceptance test was run with the pre-filter removed. The size distribution for the AC standard coarse test dust is given in Table 5. It is obvious from the size distribution of the standard test dust that if the pre-filter had been in place, approximately 75% of the solids would be retained in the pre-filter. Since no particle size distribution is available for waste lube oil from diesel engines, comparisons could not be made.

It is recommended that the first stage coalescer be first isolated from the second stage coalescer when running waste lube oil through the unit. This would assure that the second stage coalescer is kept fully operational. After running waste lube oil through the unit, the manufacturers recommend that water be recirculated through the pre-filter and first stage coalescer until the discharge water is oil free.

The bilge water separator should remove all particulate matter including aggregrated additives and insoluble metal contaminants larger than 1 micron. It is not known what effect the bilge water separator would have on soluble metal products.

A bilge water separator manufactured by SRS has been in operation aboard the 210' WMEC Alert for over one year. This unit separates approximately 12 to 15 gallons/month of bilge oil, which is mixed in the diesel fuel day tanks (12,000 gallons) and burned in the engine. No adverse engine effects have been encountered during this time. However, since the average WMEC uses about 25,000 gallons of fuel oil per month, this mixing ratio of bilge oil to fuel oil is only 0.06%, considerably lower than the recommended ratio of 1.0%.

In summation, the advantages of using the bilge water separator for waste lube oil clean-up are:

(1) Use of existing equipment

(2) Lower installation costs than with the addition of other units

(3) Lower Operating costs than with the addition of other units

(4) Crew training time minimized.

The disadvantages are:

(1) Interference with normal bilge water cleanup operation.

(2) Possible premature plugging of the first stage coalescer.

5.2.2 Lube Oil Purifiers

Lube oil purifiers of the centrifigual type are found on larger Coast Guard cutters (WHEC's and WMEC's), where they are used to treat new lube oil and purify in-use engine oil. The purifiers, manufactured by Sharples-Penwalt Corp. and the DeLeval Separator Company, are designed to treat the lube oil to military Specification MIL-P-20632A, which requires that the purified oil should not contain more than 0.05% water or 0.02% solids by volume (maximum particle size 5 microns).

For waste lube oil treatments, the viscosity should be lowered by heating or by dilution with fuel oil. It may be necessary to readjust the operating parameters of the lube oil purifier to compensate for the viscosity change.

Table 6 presents data on the effectiveness of centrifigual purifiers with waste oil. As can be seen with reference to Table 2, the sulphated ash has been reduced to values typical of the military specification for virgin lube oil.

When using a lube oil purifier for waste lube oil treatment, additional plumbing from the waste lube oil source to the unit would be required. It may be beneficial to add a pre-filter for gross solids removal. The advantages and disadvantages of using the lube oil purifier for waste oil treatment can be summarized as follows:

Advantages

(1) Use of existing equipment, where available

(2) Proven ability to reduce ash and carbon residue

(3) High efficiency removal of particulates.

TABLE 5. SIZE DISTRIBUTION OF AC DUST, BATCH #3741[6]

0-5 μ_m	12% ± 2%
5-10 μ_m	12% ± 3%
10-20 μ_m	14% ± 3%
20-40 μ_m	23% ± 3%
40-80 μ_m	30% ± 3%
80-200 μ_m	9% ± 3%

TABLE 6. RESULTS OF CENTRIFUGAL PURIFICATION OF WASTE AUTOMOTIVE LUBRICATING OIL[7]

Characteristic	As Received	Centrifuged
Carbon Residue (Conradson Carbon)	5.1%	3.8%
Ash (sulphated)	2.73%	1.85%

Disadvantages:

(1) Only available on larger cutters; installation on other cutters would be costly (~ $6,000 and up).

(2) Possible adjustment of centrifuge operating parameters.

(3) Increased maintenance.

(4) Possible contamination of cross-connected systems.

5.2.3 Special Filter Systems

A special filter system similar to that recommended by Cummins Engine Co. Inc., (Appendix C) could be installed for waste oil treatment.

The system recommended by Cummins consists of a Luber-Finer Model 750-3C filtering unit (12 inches diameter, 60 inches high). Three Luber-Finer "Diesel Pak" filters, which filter to 5 microns, are used. This system costs approximately $400 for the basic arrangement, and additional expense would be required for plumbing from the waste oil source to the unit and from the filtering unit to the fuel storage tanks. A schematic and parts list are shown in Appendix C.

The typical performance of this unit is shown in Table 7. Note that 63% of the initial ash and 73% of the residual carbon were removed. Metals were reduced by only 7%. Table 8 gives data for filtered waste diesel lube oil blended with #2 diesel fuel. Note that 1% filtered waste lube oil does not significantly change the properties of pure #2 diesel fuel (see Table 1). Ash was not included in Table 8, but an estimate can be obtained by adding 1% of the filtered oil ash content given in Table 7 to the ash content of diesel fuel given in Table 7. This would give a final ash content of 0.008% by weight.

The advantages of this filter system can be summarized as:

(1) Operable independently of other systems, thus avoiding possible increased maintainence on those systems.

(2) Readily adaptable to shore operations.

TABLE 7. RESULTS OF LUBER-FINER TREATMENT OF WASTE DIESEL ENGINE LUBE OIL[8]

Test for	Drum #2 Used Diesel Engine Oil One Hour Thru Diesel Pak		
	As Is	After Treatment[1]	%Removed[2]
Ca	1,100	1,000	9
Ba	27	26	4
P	1,150	1,100	4
Zn	1,000	950	5
Mg	440	430	2
Al	24	21	13
Pb	1,250	1,100	12
Cu	30	27	10
Fe	210	205	2
Na	33	42	(+27)
Total Emission	5,310	4,956	7
Ash (SO_4)	8,700	3,200	63
Sulfur	8,100	7,300	10
C_5 Insols.	47,300	40,000	18
Con. Carbon	24,400	6,500	73

[1]ppm

[2]Expressed as % of "as is" value

TABLE 8. ANALYSIS OF FILTERED WASTE LUBE OIL/FUEL OIL MIXTURES[8]

Composition	1	2	3
No. 2 Diesel Fuel	100%	99%	90%
Used Engine Oil[1]	--	1%	10%
Properties			
Viscosity, cSt/100F	2.1	2.17	2.74
Sulfur[2]	0.13	0.19	0.30
Total Acid No., mg KOH/gm	0.02	0.06	0.45
Filterable Solids[2] (on one micron)	nil	0.0052	0.0964
Conradson Carbon on[2] 10% bottoms	0.1	0.01	0.12

[1]Used engine oil, "as is" (Table 7)

[2]Wt. %

(3) Relatively inexpensive (~ $500/unit plus installation).

The disadvantages are:

(1) Requirement for additional on board equipment, with subsequent retraining of personnel.

(2) Cost effectiveness balanced between installation costs and possible increased maintenance costs when using bilge water separators.

5.3 MIXING RATIO

As mentioned previously, the U.S. Coast Guard fleet consumes 41,000,000 gallons of fuel oil and 400,000 gallons of lube oil. The lube oil to fuel oil ratio on a fleet basis is much less than 1%, as only a portion of the 400,000 gallons of lube oil ends up as waste lube oil.

In order to establish a mixing ratio on a class by class basis, a representative sampling of lube oil and fuel oil use of some cutters was undertaken.

On a WHEC 378', the lube oil capacity of each main diesel engine is 340 gallons. Conversations with ship engineering departments indicated that the oil in these engines is changed on the average every 9 to 10 months. Assuming the worst case possibility of changing oil in both engines at once (a rare occasion), 680 gallons of waste lube oil would be available for treatment. The main fuel tank capacity of the 378' is ~ 200,000 gallons. The waste oil would only by 0.3% of the total fuel if mixed in the fuel when the tank is full. The main fuel tanks would have to be less than 35% full before the 680 gallons of waste lube would exceed the 1% mix ratio. If the 680 gallons were dumped into the day tanks of a 378' WHEC (28,000 gallons), the mix ratio would be 2.5%.

On a 210' A WMEC the lube oil is changed every 500 hours or before, if the emission spectrographic or viscosity analysis indicate a need. This change would produce 250 gallons of waste lube oil. The main and day tank fuel capacities of a 210' A are 36,000 and 12,000 gallons respectively. This would yield a mix

ratio of 0.7% and 2% in these tanks.

The lube oil on a 210' B-WMEC is changed only when required by viscosity tests or spectrographic analysis. Each engine holds approximately 220 gallons of lube oil (440 gallons if both engines are changed). The mix ratio in the 36,000 gallon main tank would be 1.2%; in the 6,000 gallon day tank, 7.5%.

On a 95' WPB the lube oil is changed every 500 hours or sooner, if required. This change produces 50 gallons of waste lube oil. The 95' WPB has three 980 gallon fuel tanks and one 1150 gallon fuel tank. The day tank capacity is 150 gallons. This would result in a mix ratio of 5% and 4.3% in the main tanks and 30% in the day tank. If the lube oil were evenly distributed among the four main tanks the mix ratio would be 1.2%.

From the proceeding examples the following conclusions can be drawn:

(1) The smaller the ship, the more care must be taken in the mixing of the filtered waste lube oil.

(2) In order to keep the mix ratio as low as possible the waste lube oil should be dumped into the main fuel tank (or evenly distributed in a multi-fuel-tank cutter).

(3) The method of mixing should be determined on a class-by-class basis.

It should be emphasized that the preceeding examples were worst cases. It is recommended, however, that each class of cutters have their own standard operating proceedure for mixing waste lube oil with fuel oil, and a further study by Coast Guard Naval engineering would be in order, especially for smaller cutters. It may be necessary to burn-off only part of the waste lube oil at any one time in order to keep the mix ratio as low as possible. However, 1% is a conservative mix ratio and accidental, periodic operation of engines with a mix ratio of 5% probably would not be harmful.

6. EFFECTS OF BURNING WASTE LUBE OIL IN COAST GUARD POWER PLANTS

Although this report primarily addresses ifself to the burn-off of waste lube oil in Coast Guard diesel engines, it is appropriate to consider the effects of burning waste lube oil, at the recommended mix ratio, on oil-fired boilers and gas turbines. Each of these are considered in detail in the following sections.

6.1 EFFECTS ON DIESEL ENGINE PERFORMANCE

Most of the lube oil burn-off programs conducted to date have encountered no adverse effects on diesel engine performance. However, certain precautions must be taken in regards to waste lube oil treatment to assure proper engine operation. Proper filteration of particulates and removal of water must be stressed, since these materials, present in sufficient quantities, produce injector wear. These materials could also cause premature plugging of the in-line fuel filters and wear of the fuel pumps.

The overwhelming majority of tests performed by others in lube oil burn-off programs (Section 3) have indicated that no adverse internal damage is encountered when properly treated waste lube oil is burned in diesel engines. Only Detroit Diesel Allison, Division of GMC, does not endorse a continuous lube oil burn-off program. This reluctance is based on a study performed by Detroit Diesel in answer to users' desires to burn waste lube oil in Detroit Diesel engines.[9] Detroit Diesel has always recommended use of low ash (1.0% by weight) lubricating oil in their diesel engines; their recommended diesel fuel contains only 0.01% ash by weight. In order to illustrate the effect of high ash content (1.0-5.0% by weight) in lubricating oils used for lubrication Detroit Diesel performed the following test: Various ash content lubricating oils were used as lubricating oils in the crankcase of a test engine subjected to a 531-hours laboratory dynamometer test cycle. Figures 3, 4, and 5 show the deposit levels experienced when a lubricating oil having 2.2% by weight

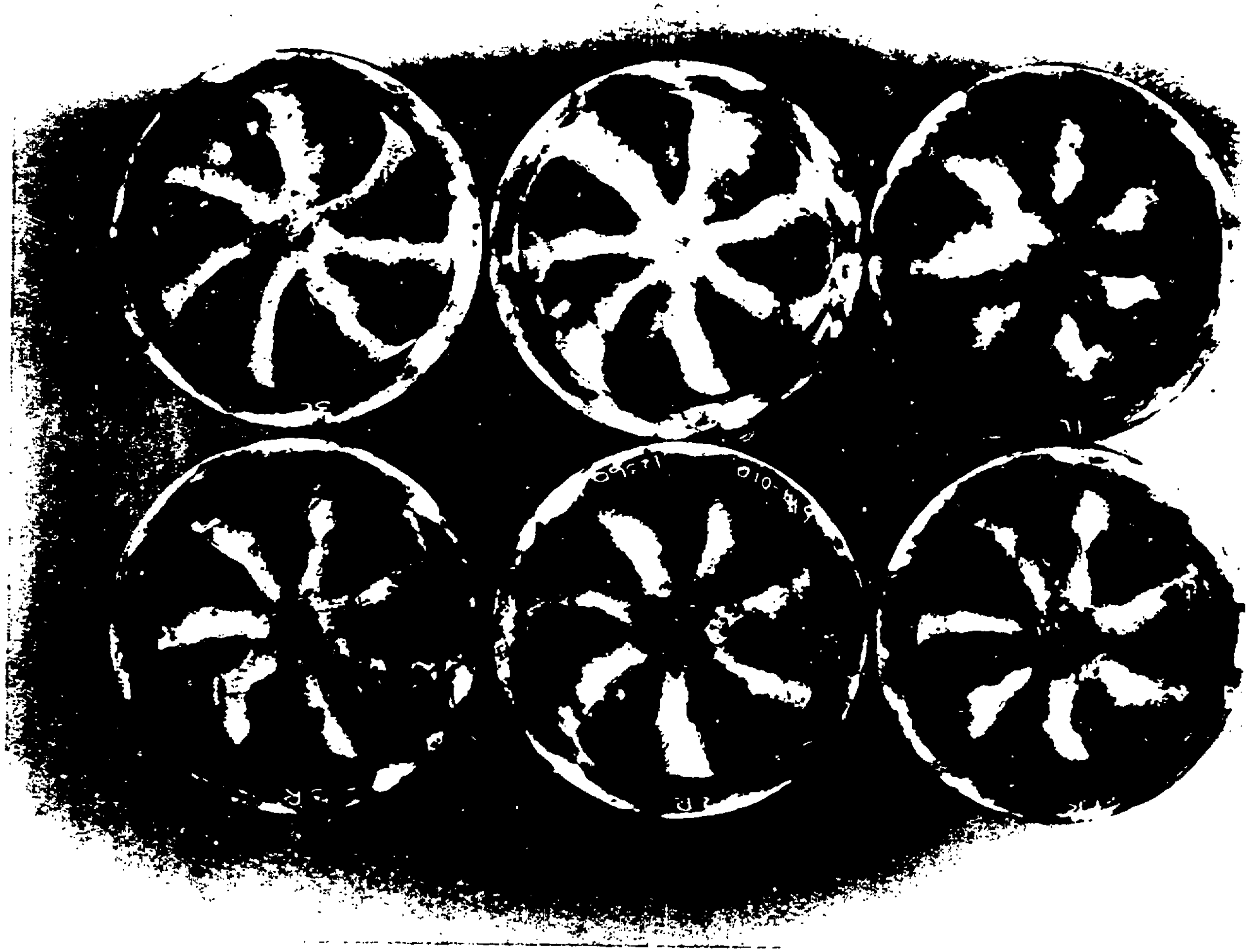

Figure 3. Ash Deposits on Pistons, 2.2% by Weight Sulphated Ash in Lubricating Oil

Figure 4. Ash Deposits on Valve Surfaces, 2.2% by Weight Sulphated Ash in Lubricating Oil

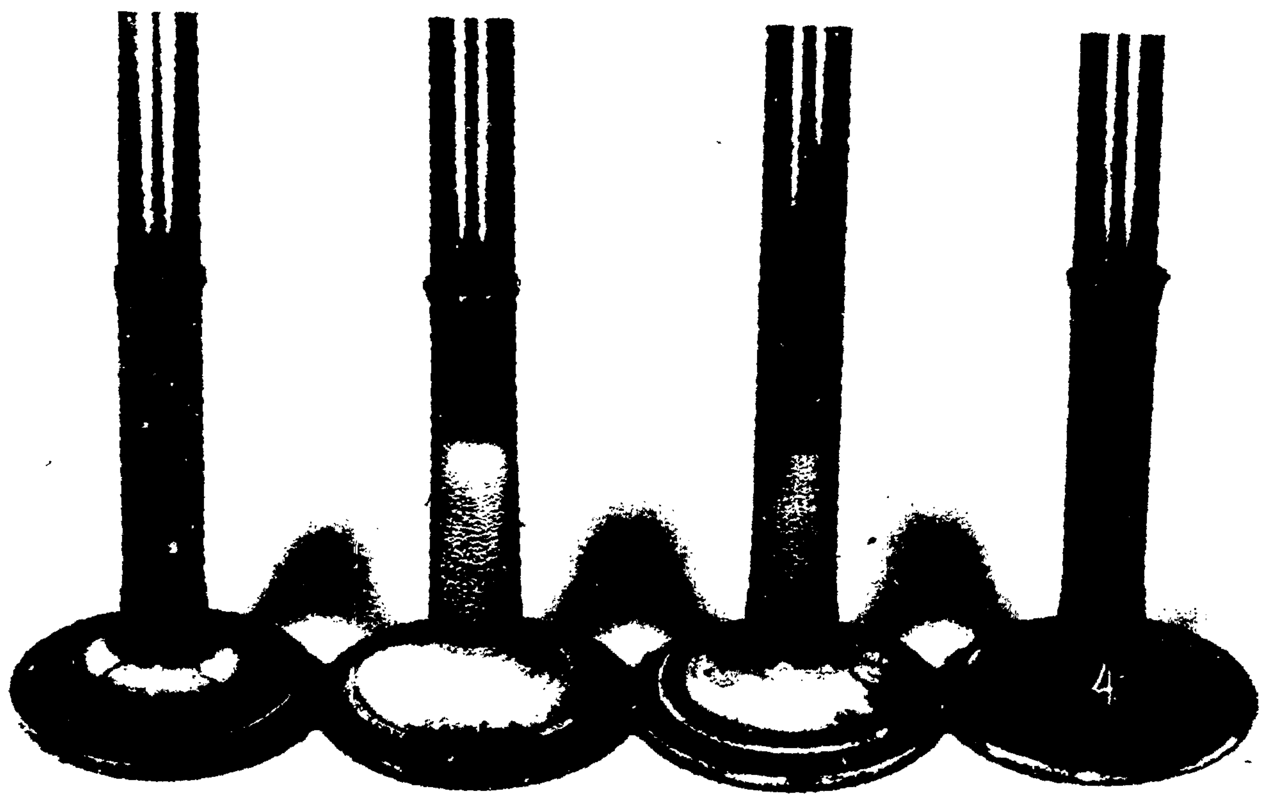

Figure 5. Ash Deposits on Valve Stems, 2.2% by Weight Sulphated Ash in Lubricating Oil

(~2.0% by volume) sulphated ash content was used as lubricating oil in the test engine. Figures 6, 7 and 8 show the deposit levels when a lubricating oil having a 1.0% by weight (~0.93% by volume) sulphated ash content was used as lubricating oil in the test engine. Figures 9, 10, and 11, show the relatively light deposits produced when a commercial ashless oil was used as lubricating oil in the test engine.

The effects of burning waste lube oil mixed with fuel oil in a diesel engine were estimated in a hypothetical case by Detroit Diesel. Table 9 describes the hypothetical operating conditions of a diesel powered highway truck. Table 10 lists the results of the hypothetical test of the diesel powered high truck after 100,000 miles of continuous operation. In this test 5.0% by weight (4.65% by volume) of the drained lube oil (1% ash by weight) was burned in the diesel fuel.

Developing the same hypothetical case for a Coast Guard engine burning 1% by volume waste lube oil of a 2% ash content (typical military specification MIL-L-90006 1.5-2.0%) would yield the results given in Table 11. The calculation shows that continuously burning 1% lube oil in diesel fuel for 2,500 hr (100,000 miles) produced 67.4 pounds of ash based on Detroit Diesel's hypothetical calculation. This is in contrast to 29.9 pounds of ash produced if no lube was burned in the diesel fuel. Therefore, burning 1.0% by volume waste lube oil in diesel fuel produces 2.2 times the amount of ash produced in a normally operating engine burning no lube oil in the diesel fuel.

It should be emphasized that this is a calculation and has not been verified by laboratory tests by Detroit Diesel. Furthermore, Figures 3 through 11 reflect results of tests using high ash content lubricating oil for lubrication and not results from burning lube oil in diesel fuel. Moreover, the production of 2.2 times as much ash as using 1.0% waste oil in diesel fuel is based on continuous operation over 100,000 miles. In the Coast Guard case the lube oil burn-off procedure will not be continuous and thus the amount of ash produced in 2,500 hr will be significantly less.

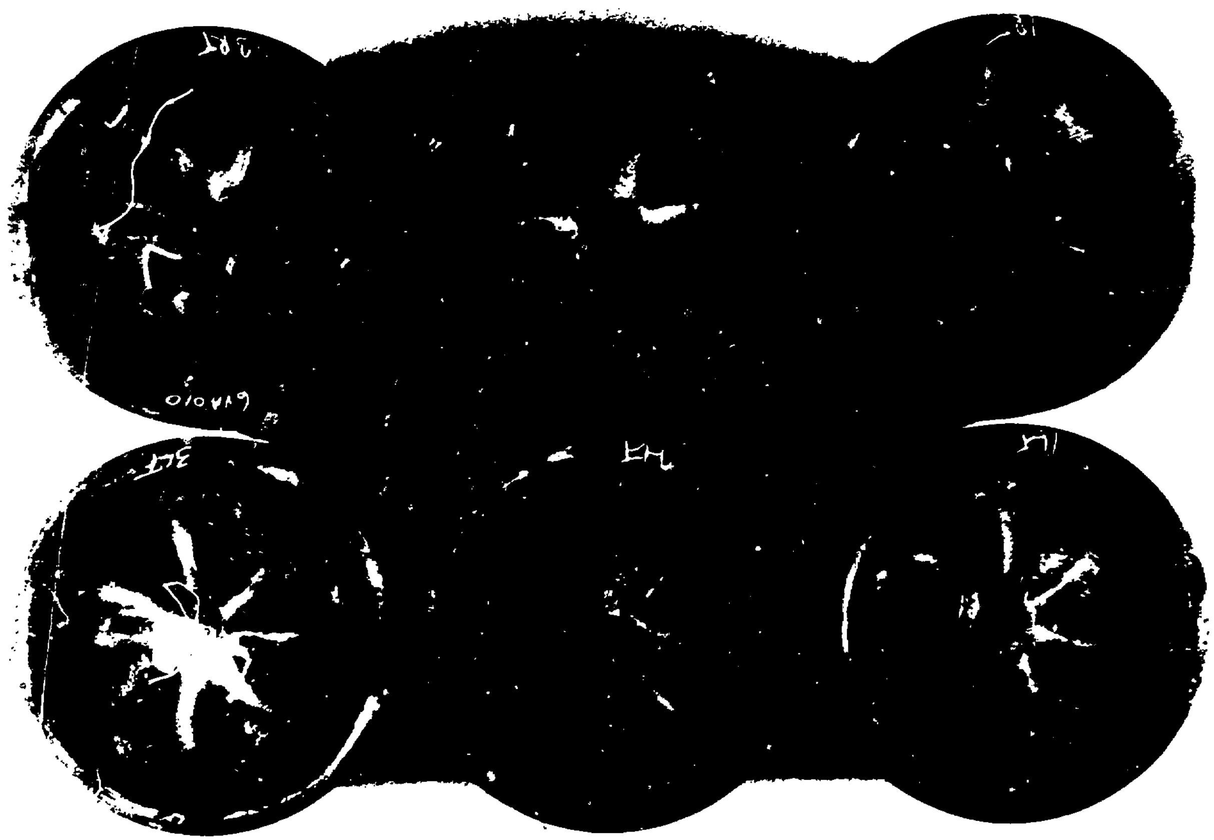

Figure 6. Ash Deposits on Pistons, 1.0% by Weight Sulphated Ash in Lubricating Oil

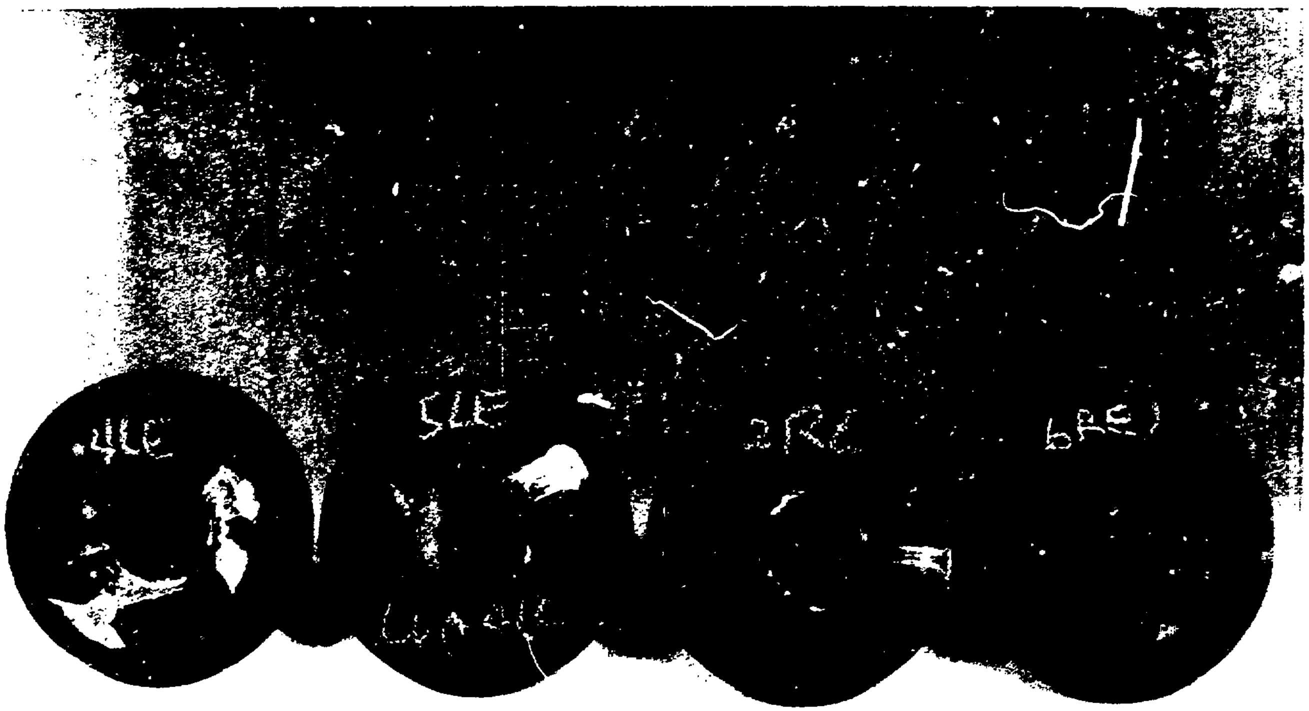

Figure 7. Ash Deposits on Valve Surfaces, 1.0% by Weight Sulphated Ash in Lubricating Oil

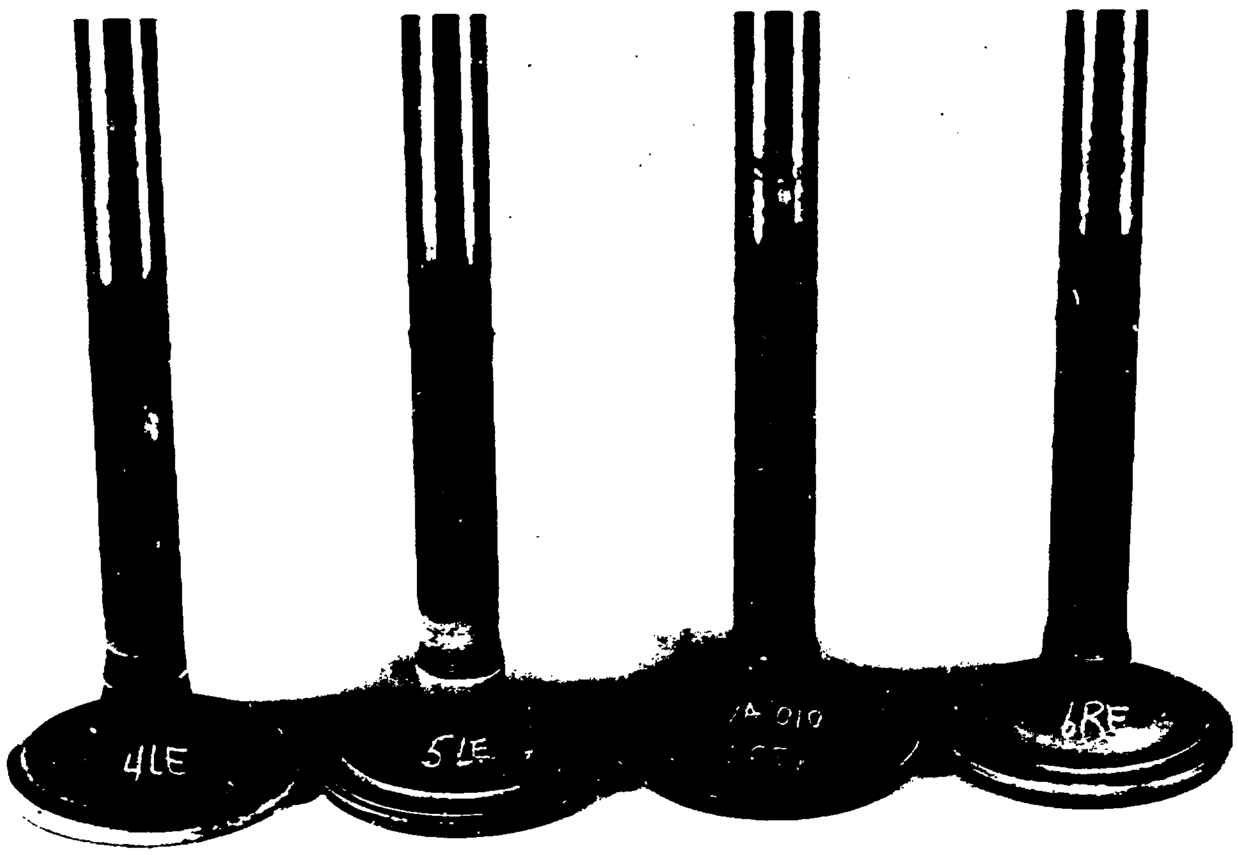

Figure 8. Ash Deposits on Valve Stems, 1.0% by Weight Sulphated Ash in Lubricating Oil

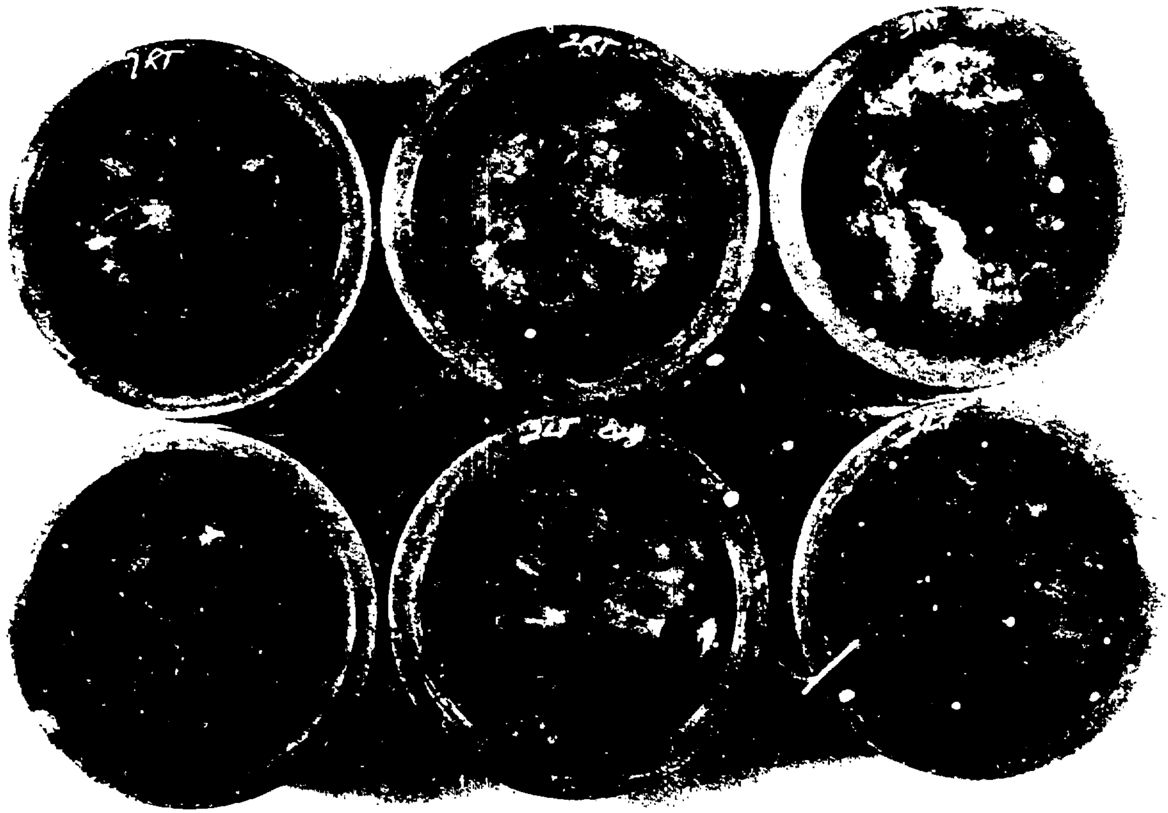

Figure 9. Ash Deposits on Pistons, Ashless Lubricating Oil

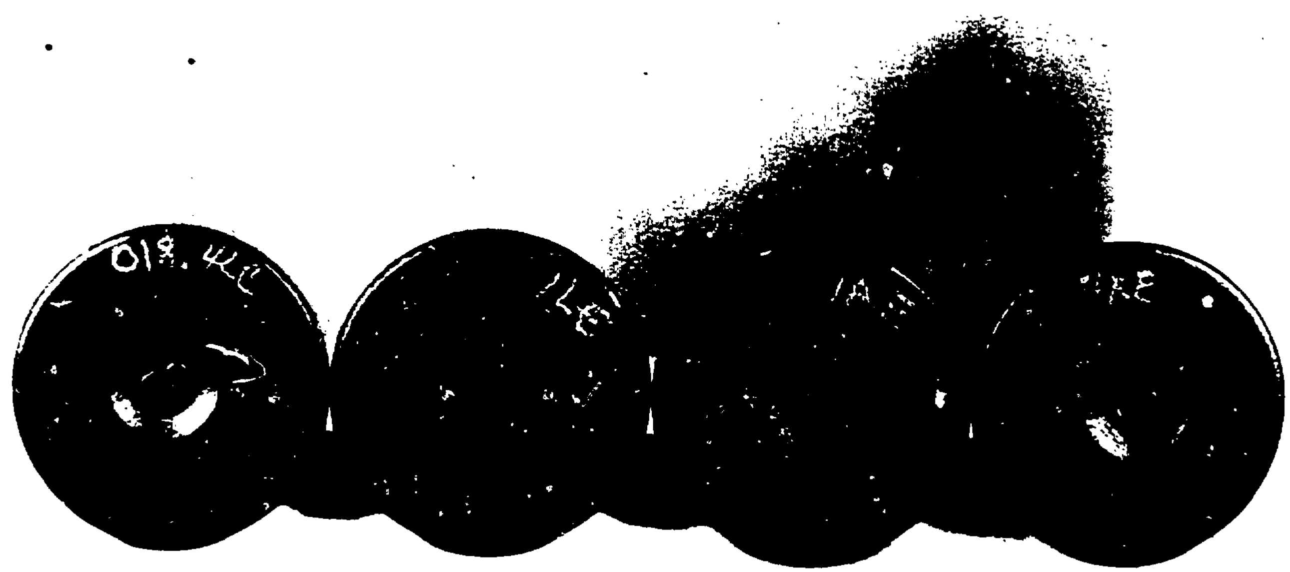

Figure 10. Ash Deposits on Valve Surfaces, Ashless Lubricating Oil

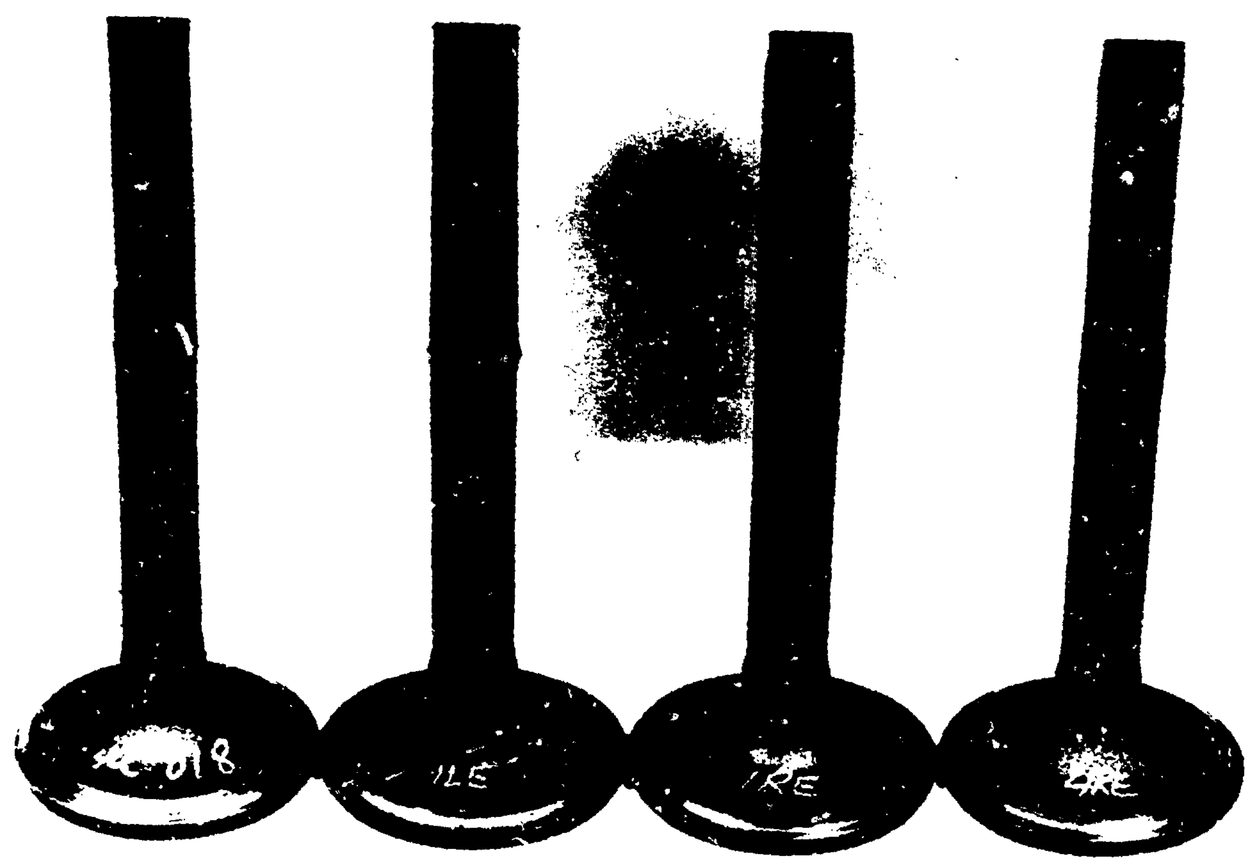

Figure 11. Ash Deposits on Valve Stems, Ashless Lubricating Oil

TABLE 9. ENGINE OPERATING CHARACTERISTICS, HYPOTHETICAL CASE[9]

Engine Road Speed, MPH...............	40
Fuel Economy, M.P.G..................	4
Lube Oil Economy, M.P.Q..............	300
Ash Content of Lube Oil, wt %........	1.0
Amount of Drained Lube Oil in Diesel Fuel...................	5.0

TABLE 10. FLUIDS CONSUMED AND POTENTIAL ASH FORMED AFTER 100,000 MILES OPERATION, 5% BY VOLUME LUBE OIL BURNED IN DIESEL FUEL[9]

Gallons of Crankcase Lube Oil Burned.......	84
Pounds of Crankcase Lube Oil Burned........	622
Pounds Lube Oil Ash Produced from Crankcase Oil (1.0% Ash)...........	6.2
Gallons Fuel Burned........................	25,000
Pounds Fuel Burned.........................	175,000
Gallons Lube Oil Burned in Diesel Fuel.........................	1,250
Pounds Lube Oil Burned in Diesel Fuel.........................	9,250
Pounds Ash Produced from Lube Oil (1.0% Ash) in Diesel Fuel..................................	92.5
Pounds Ash Produced from Diesel Fuel (0.01% Ash).................	17.5
Total Pounds Ash Produced in 100,000 Miles.......................	116.2

TABLE 11. FLUIDS CONSUMED AND POTENTIAL ASH FORMED AFTER 2,500 HOURS OPERATION, 1% BY VOLUME LUBE OIL BURNED IN DIESEL FUEL

Gallons of Crankcase Lube Oil Burned........	84
Pounds of Crankcase Lube Oil Burned.........	622
Pounds Lube Oil Ash Produced from Crankcase Oil (2.0% Ash).............	12.4
Gallons Fuel Burned.........................	25,000
Pounds Fuel Burned..........................	175,000
Gallons Lube Oil Burned in Diesel Fuel.........................	250
Pounds Lube Oil Burned.........	1,875
Pounds Ash Produced from Lube Oil (2.0% Ash) in Diesel Fuel................	37.5
Pounds Ash Produced from Diesel Fuel (0.01% Ash)	17.5
Total Pounds Ash Produced in 2500 hr (100,000 Miles).......................	67.4

6.2 OIL FIRED BOILERS

The burning of waste lube oil in oil fired boilers is an accepted practice in industry.[10 11] Much of the water in the oil is removed by settling,with filtration to 100 microms to remove gross particle contamination. The lube oil is then blended with the fuel oil in varying amounts up to 100%. No problems have been encountered in burning waste lube oil in this manner, since the waste product is usually of higher quality than the fuel it replaces (#5 or #6 fuel oil). Tests conducted by the American Petroleum Institute and reported by Mobil Oil Corp.[12] indicated good results when waste lube oil was burned in various types of boilers, either blended with #6 oil or as straight waste oil. Generally, Mobil supports mixing up to 25% waste lube oil in heavy fuel oils. Babcock and Wilcox Co. indicated that 1.0% waste lube oil blended with Navy Special, as burned on a 327' WHEC, would be acceptable.

The treatment recommended for waste lube oil burn-off in diesel engines would produce a product acceptable for burn-off in hotel-service type boilers presently using #2 distillate. Boilers are much less susceptiable to particulate and water contamination (up to 8% water if blended homogenously) than diesel engines. No problems will be encountered with this type boiler, especially at the recommended mix ratio of 1.0%. It is anticipated that no adjustments will be necessary in the combustion parameters, such as feed rate, air/fuel ratio, etc. There may be a slight increase in ash deposits in the fire box and boiler tubes. However, it is doubtful that maintainence requirements will be increased.

6.3 GAS TURBINES

If waste lube oil is mixed with #2 diesel fuel on 378' WHEC's, 210' A WMEC's and the new class of Polar Icebreaker, consideration must be given to the use of the lube oil/fuel oil mix in gas turbines. Since the turbines run on #2 diesel fuel, they receive their fuel from the same tanks which serve the main diesel engines.

According to Pratt and Whitney Aircraft and General Electric Co., light distillate fuels, such as #2 diesel fuel, can be used in

gas turbines if the fuel meets manufacturers specifications or military specifications MIL-F-16884F (see Table 1). Fuel requirements for gas turbines are more stringent than for diesel engines since certain metals and sulphur produce "hot corrosion" or "sulphinization" of turbine blades. Therefore, if waste lube oil is to be used with #2 diesel fuel in gas turbines, the values of the important characteristics of the blended fuel should fall within military specification MIL-F-16884F or Pratt and Whitney's PWA 527 specifications.

Typical specifications recommended by Pratt and Whiteny for gas turbines using light distillate fuel (#2 diesel fuel) are shown in Table 12. In order to minimize the effect of lube oil on the turbines, the ash, trace metal (Na, K, Pb, Va, Ca), and sulphur content of a waste lube oil/fuel oil mix must be below those values given in Table 12. Table 13 lists values of the important characteristics of waste lube oil and a hypothetical 1% lube oil/fuel oil mix.

As can be seen from Table 13, the values of the 1% mix fall close to the specification values of PWA-527. General Electric gas turbine fuel requirements are shown in Table 14. As can be seen from this table, General Electric's lead requirement is 1.0 ppm, and the calcium requirement is 2.0 ppm. The values of calcium and lead from the 1% mix exceed these values, and the 1% mix is not an acceptable fuel. It should be noted that this is only a hypothetical waste oil sample and may or may not be representative of specific Coast Guard sample. Therefore, the following recommendations are made for lube oil burn-off in 378' WHEC, 210' A WMEC, and new Icebreakers:

(1) An analysis of the waste lube oil should be performed after treatment before the lube oil is mixed in the fuel tank.

(2) From the lube oil analysis data a mix ratio should be determined to meet PWA-527.

(3) If a reasonable mix ratio is not possible for burn-off of the entire waste lube oil supply, it is then

TABLE 12. PRATT AND WHITNEY FT4A GAS TURBINE FUEL REQUIREMENTS PWA-527[13]

Characteristics	Value
Sulphur	1.0% by weight
Carbon Residue (10% bottoms)	0.1% by weight
Ash	0.005 by weight
V	0.1 ppm
Na + K	0.2 ppm
Ca	0.1 ppm
Pb	0.1 ppm
Cu	0.02 ppm

TABLE 13. CHARACTERISTIC PROPERTIES OF #2 DIESEL FUEL, GAS TURBINE FUEL, WASTE LUBE OIL, AND 1% LUBE OIL/FUEL OIL MIXTURE

Characteristic	#2 Diesel Fuel* MIL-F-16884F	PWA-527	Waste** lube oil	1% mix
Carbon Residue	0.20% max	0.1%	0.65%	0.207% (max)
Sulphur	1.00% max	1.0%	0.73%	1.007% (max)
Na + K	-	0.2 ppm	42 ppm***	0.4 ppm
V	-	0.1 ppm	0.2 ppm	0.002 ppm
Ca	-	0.1 ppm	1000 ppm	10 ppm
Ash	50 ppm	50 ppm	3200 ppm	82 ppm
Pb		0.1 ppm	1000 ppm	10 ppm

*Data from Table [illegible]

**Data from Table

***Data from Table 4

TABLE 14. GENERAL ELECTRIC GAS TURBINE FUEL REQUIREMENTS[14]

PROPERTY	TRUE DISTILLATES	
	LIGHT	HEAVY
Kin. Viscosity, cSt, 100°F (37.8°C), min	.5	1.8
Kin. Viscosity, cSt, 100°F (37.8°C), max	5.8	30
Kin. Viscosity, cSt, 210°F (98.9°C), max	-	4
Specific Gravity, 60°F (15.6°C), max	Report	Report
Flash Point, °F (°C), min	Report	Report
Distillation Temp. 90% Point, °F, (°C), max	650 (338)	Report
Pour Point, °F (°C), max	0(-18) or 20 (7) below min. ambient	Report
Carbon Residue, Wt. % (10% Bottoms) max Direct Pressure Atomization	.25	-
Carbon Residue, Wt. % (100% Sample) max Air Atomization, Low Pressure	1.0	1.0
Carbon Residue, Wt. % (100% Sample), Air Atomization, High Pressure	-	-
Ash, ppm, max	50	50
Trace Metal Contaminants, ppm, max		
Sodium plus Potassium	1	1
Lead	1	1
Vanadium (untreated)	.5	.5
Vandium (treated 3/1 wt. ratio Mg/V)	-	-
Calcium	2	2
Other Trace Metals above 5 ppm	Report	Report
Filterable Dirt, mg/100ml, max	4	40
Water & Sediment, Vol. %, max	.1	.1
Thermal Stability, Tube No., max	-	2
Fuel Compatibility, Tube No., max (50/50 mix with second fuel)	-	2
Cetane No., min (Diesel Engine Start Only)	40	-
Sulfur, Wt %, max	.5%	0.5%

recommended that the waste lube oil be burned-off in smaller quantities over a longer period of time, such that PWA-527 is satisfied.

Another alternative is not to run the turbines when burning-off waste lube oil. This may not be a viable alternative, however, considering the quick-reaction requirements of the Coast Guard.

7. EMISSIONS

The addition of filtered lube oil into diesel fuel oil at a 1% or smaller level is not expected to increase diesel engine emissions. Cummins Engine Co. Inc., has measured emissions from a turbo-charged and a naturally aspirated diesel engine burning a mixture of up to 10% new lubricating oil by volume with No. 2 diesel fuel. The following results were obtained:[15]

(1) A 30% to 40% reduction in acceleration and lug down smoke occurred with a 5% lubricating oil mixture in naturally aspirated engines. This reduction decreased to 20-25% at a 10% lube oil mixture.

(2) There was no appreciable difference in smoke level with turbo-charged engines.

(3) There was a slight reduction in brake specific carbon monoxide (BSCO).

(4) There was an insignificant increase in brake specific hydrocarbons (BSHC) with lube oil mixtures up to 5%. Above 5% the increase in BSHC was significant.

(5) There was no significant change in brake specific oxides of nitrogen (BSNO).

(6) There was no measurement of polynuclear aromatics and metallic oxides emissions.

The U.S. Bureau of Mines carried out a series of emission tests at the request of TSC. Two identical tests using the eleven mode-average emission cycle were obtained on a Caterpillar D333-C, precombustion chamber, naturally aspirated engine. A 1% by volume of new lube oil was used in #2 diesel fuel. The data for a test without oil and for two tests with oil are shown in Table 15.

These data show no increase in emissions for this type of engine (Appendix D). It would be beneficial to verify these emissions results on common Coast Guard engines through laboratory or field testing.

TABLE 15. EMISSION DATA, CATERPILLAR D333-C ENGINE RUN ON 1% LUBE OIL/FUEL OIL, 11-MODE AVERAGES

TYPE OF EMISSIONS	WITHOUT OIL	WITH OIL	WITH OIL
Power	50.71	50.42	50.72
BSFC(lbs/hp hr)	0.5287	0.5322	0.5245
BSCO(gms/hp hr)	1.71	1.73	1.62
BSNOX(gms/hp hr)	4.49	4.33	4.32
BSHC(gms/hp hr)	0.81	0.48	0.41
Smoke (%, opacity)	2.3	1.8	3.6

8. PROCEDURES

Specific procedures to be used on shipboard will depend on the type of filtration system selected. In general, waste lube oil is pumped from its source (engine, running gear, or bilge) to the treatment system. Prior to treatment, dilution with fuel oil at about a 1 to 3 ratio (to assure adequate mixing) is recommended. The filtered product should then be returned to the main fuel tank(s) for reasons described in section 5.3.

For shore operations, a pump, filter system, and storage barrel could be set up on a mobile cart for ease of movement from oil source to oil source. The waste lube oil would be pumped into the storage barrel and subsequently returned through the filter, with fuel oil dilution, to the boat fuel tanks.

In both ship and shore operations care must be taken to assure that the recommended 1% mix ratio is not exceeded. On shipboard, it is recommended that a new entry be added to the machinery log in the fuel and water record. Whenever the waste lube oil is added to the fuel tanks a notation should be made in the fuel record and the mix ratio calculated, based on that day's fuel tank soundings. An identical running record should be kept on a card or tag near the valve controlling the flow of waste lube oil to the fuel tanks.

On shore, a similar running record should be kept for each boat that burns waste lube oil. In both ship and shore operations, fuel flow meters should be installed to monitor the amount of waste lube oil added to the fuel tanks.

9. COSTS

The most cost-effective approach is through the utilization of existing equipment whenever possible. Lube oil purifiers are in use on large cutters and bilge water separators are presently being installed on all cutters down to 65 ft.

Utilizing existing equipment would limit additional costs to plumbing, pumps, valves, fittings, etc. These additional costs would be difficult to ascertain at this time, since each installation must be considered on a class basis.

Additional costs would be entailed should it be decided that a separate pre-filter ahead of existing equipment is required. The cost of this unit is approximately $60 plus installation costs.

If a new filtering system, such as that recommended by Cummins, is installed, either on board ship or at shore installations, then an additional cost of $500 per unit plus installation would be realized. This additional cost for the filter units alone would be $145,000 on a fleet wide basis, plus costs for shore installations.

Balanced against these costs are the potential savings realized through substitution of one gallon of waste lube oil for one gallon of fuel oil (approximately $0.50, based on fuel costs and waste lube oil disposal costs). The potential savings, therefore, would be approximately $200,000 per year. Real savings would be somewhat less due to lost lube oil. We are confident, however, that a fleet-wide minimum cost waste lube oil burn-off program would pay for itself in four or five years.

10. MAINTENANCE

Any treatment systems, whether utilizing existing equipment or adding new equipment, will increase the maintenance load placed on the ship's engineering department or shore personnel. However, anticipating the expected waste lube oil load, this maintenance should be minimal, consisting of filter changes and/or cleaning of the centrifuge bowl. Use of the bilge water separator would require the additional task of regeneration by water circulation through the coalescers.

11. RECOMMENDATIONS

(1) Waste lube oil produced by Coast Guard operations should be burned off in Coast Guard power plants after mixing with fuel oil at a ratio of 1% or less waste lube oil to fuel oil.

(2) Prior to burning, the waste lube oil should be treated to remove harmful contaminants. The most cost-effective approach would utilize bilge water separators, presently being installed on cutters, for this treatment.

(3) A series of tests should be run to determine the effectiveness of bilge water separators, lube oil purifiers, and/or filter assemblies for removing harmful contaminants from waste lube oil. Waste crankcase oil, running gear oil, and bilge oil should be analyzed before and after treatment. Emphasis should be on the more stringent fuel requirements for gas turbine operation. These tests should answer the question of the need for additional pre-filters and/or first stage filter changes in the bilge water separators and mixing procedures.

(4) Tests should be conducted on common engines in the Coast Guard fleet using the treated waste lube oil mixed at the recommended ratio to determine any possible adverse effects on engine performance and emissions.

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APPENDIX A
INFORMATION SEARCH

The following references were compiled by the Technical Information Center of the Transportation Systems Center.

The references in this bibliography are divided into three sections; analysis and evaluation of used lubricating oil, reclamation refereoses, and patents and contracts. It includes foreign language articles and patents, as well as those in English as there appears to be much patent activity in this field. I have included in some foreign language cases the Chemical Abstracts abstract number so atleast the abstract can be found.

Indexes Searched and Terms used.

Applied Science and Technology Index 1970-74	lubricating oils, oil reclamation
Chemical Abstracts 1970-74	lubricating oils-used
Engineering Index 1971-74	lubricating oils-reclamation
Environmental Index 1971-72	oily wastes
Fuel Abstracts 1970-74	by-products derivable from fules and lubricants
U.S. Government Reports Index 1970-74	lubricants-oils-recovery
Institute of Petroleum Abstracts 1969-72	lubricants used, lubricants-regeneration
Pollution Abstracts 1970-74	oily wastes, waste utilization
Tribos 1970-74	lubricants-oils-recovery

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APPENDIX B

ENGINE MANUFACTUERS' LETTERS

Allis-Chambers
Babcock & Wilcox
Caterpillar Tractor Co.
Colt Industries
Cooper-Bessemer Co.
Cummins Engine Co., Inc.
Detroit Diesel Allison Division, GMC
General Electric - Gas Turbine Product Division
International Harvester Co. - Construction Equipment Div.

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ALLIS-CHALMERS

BOX 563 • HARVEY, ILLINOIS 60426/312-339-2300

ENGINE DIVISION

August 6, 1974

Dr. John R. Hobbs
Code 641
U. S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge, Massachusetts 02142

Dear Dr. Hobbs:

Confirming this morning's telephone conversation, we have reviewed the contents of my letter of June 11 to your Mr. Sabo on the subject of the reuse of waste lube oil as additive to fuel oil.

You advise that you are contemplating additions of lube oil not to exceed 1 or 2%. You also confirm that it is intended to filter particulates out of the used lube oil to an approximate level of 10 microns.

We feel that the precautionary measures and lube oil percentages which you are proposing would be quite acceptable: we would not expect any adverse effects on engine performance or wear, as long as these conditions are observed.

Sincerely yours,

Dr. A. Dreisin
Manager, Engineering

kb

Babcock & Wilcox

Power Generation Group
Barberton, Ohio 44203
Telephone: (216) 753-451'

9118

October 18, 1974

Transportation Systems Center
Kendall Square
Cambridge, Mass. 02142

Attention: Mr. John R. Hobbs

Subject: TSC Ltr., Code 641, dated 9/27/74
Burning of Lube-Oil/Fuel-Oil Mix

Gentlemen:

The subject letter has been reviewed by the B&W Design and Engineering people and the following comments are offered:

The low percentage lube-oil/fuel-oil mixture (1%) should not be detrimental to the boiler burning mechanism, nor should it be significant to increased corrosion or fouling of heat transfer surfaces.

However, due to the high ash content of the waste lube-oil, the frequency of blowing soot may be increased since more fireside deposits could be expected. Frequent fireside inspections should be made to determine the adequacy of the soot blowing and boiler performance should be monitored closely to detect increases in exit gas temperature or increases in boiler draft losses, both indicative of fouled heat transfer surfaces.

Use of filtered waste lube-oil vs. unfiltered oil is advantageous from the standpoint of reduced wear to the fuel oil system, especially sprayer plates.

If we can assist you further in this matter, please contact us.

Very truly yours,

W J Miller/JH.

W. J. Miller
Project Manager
IMD Project Management, Marine

WJM:oh

CATERPILLAR TRACTOR CO.

INDUSTRIAL DIVISION

Peoria, Illinois 61602

June 13, 1974

U. S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge, Massachusetts 02142

Gentlemen:

TIM Letter Dated May 31, 1974

In reply to your inquiry of the above, Caterpillar does recognize the benefit of using waste lube oil. Because of all the variables that are difficult to control and could lead to more difficulties, we recommend a maximum of 5% spent crankcase oil be mixed with diesel fuel. The quantity of lube oil generated for eventual disposal will normally fall well within the 5% lube oil-to-fuel ratio limit.

The following precautions must be adhered to for satisfactory useage.

1. Diesel engine crankcase oils and hydraulic oils of the same type as used in the engine can be mixed with a 5% (maximum) oil-to-fuel ratio. Do not use crankcase oils containing water or antifreeze.

2. Adequate mixing is essential. Lube oil and fuel oil are miscible; once they are mixed, they will stay mixed.

3. Primary filtering of 5 microns (nominal) between the fuel tanks and the engine is strongly recommended. Soot, dirt, wear particles, and oxidized fuel and oil residues will not separate out of the oil/fuel mixture and will plug engine fuel filters if not removed.

4. Clean handling techniques of the used crankcase oils are essential to prevent introducing contaminates from outside sources into the diesel fuel supply.

The above recommendations can minimize the risks and inconveniences in burning crankcase oils with diesel fuel. However, the following precautions are offered for consideration.

1. Fuel filter plugging will be accelerated if: (1) the oil-to-fuel ratio is too high, (2) a slug of straight, undiluted oil reaches the engine filters, (3) the lube oil and diesel fuel are not adequately mixed, (4) the used crankcase oil added to the diesel fuel contains a large amount of soot, or (5) the oil/fuel mixture is not centrifuged or filtered prior to the engine fuel tank.

2. Caterpillar engine lube filters are a 15 micron (nominal) filtering capability while the engine fuel oil filters are with a 5 micron filtering capability.

3. Accelerated fuel pumps wear and fuel nozzle erosion or plugging may be experienced if a sufficient quantity of metal particles have been introduced to the diesel fuel supply with the crankcase oil.

4. Particulate matter in exhaust plus valve and turbocharger deposits will be increased due to the higher ash content of the oil/fuel mixture relative to normal clean diesel fuels.

Providing the above is strictly adhered to and primary filtering with proper care in collecting used crankcase oil, we believe satisfactory results can be achieved.

We trust the above will help you with your project. If you have further questions, please let us know.

Very truly yours,

W. McEnary

Market Development Representative
Support Services Division
Defense Products Department

WMcEnary
Telephone: 309/578-6048
clb

Colt Industries

Power Systems Division
701 Lawton Avenue
Beloit, Wisconsin 53511
608/364-4411

August 26, 1974

Mr. Robert A. Walters
U.S. Department of Transportation
Transportation System Center
Kendall Square
Cambridge, MA 02142

Dear Mr. Walters:

This will confirm our conversations relative to burning lube oil in a diesel engine. Lube oil removed from engine crankcases can be burned in the engine providing:

1. The lube oil is properly cleaned - i.e. the water, ash, dirt, and metallic material is removed.

2. The rate of ingestion into the engine is kept reasonably low - less than 2% of the fuel rate.

Treatment of the waste oil should be adequate to bring it within engine fuel specifications relative to Ash, Bottom Sediment, and Water. Centrifuging followed by good filtering should do the job; however, it would be necessary to analyze the oil before and after treatment initially and some type of monitoring after the system is operational.

I am enclosing our fuel oil specification D3063A1, sheets 1 and 2.

The limit on the rate at which lube oil could be burned is to insure that the Cetane Number and other properties of the "fuel" the engine would see are not materially changed.

Finally, as other manufacturers have probably stated, burning of used lube oil in an engine would negate any FM warranty on fuel handling system, injection system, power cylinder or turbocharger. The reason for this is that the procedure will likely be a vessel by vessel type of operation and the possibility of a loss of control on the used lube oil conditioning is more likely.

Yours truly,

COLT INDUSTRIES OPERATING CORP.
FAIRBANKS MORSE ENGINE DIVISION

Charles L. Newton

Charles L. Newton
Manager, Development Engineering

CLN:bjp
Enclosures
cc: T. J. Bullock

A division of the Colt Industries Operating Corp

COOPER INDUSTRIES

COOPER-BESSEMER COMPANY

June 6, 1974

U. S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge, Massachusetts 02142

Attention: Cadet 1/C James Sabo

Reference: TIM

Dear Sir:

The use of waste lubricating oil as a fuel for diesel engines has been practiced for many years by various operators as a means for disposal of their crankcase drainings. Their method of operation has been simply to add several drums of the used oil to fuel storage and depend on the fuel system strainers and filters to remove extrinsic material.

The above does not, of course, represent a continuous operation on a high percentage of waste lube oil, a condition which your letter implies.

Lubricating oil, exclusive of its additive package, would in itself be an admirable diesel fuel, needing only sufficient heat or dilution to provide an acceptable viscosity for injection (i.e., 70 S.U.S. max.). A straight mineral lubricating oil having a viscosity of 750 S.U.S. @ 100°F could be heated to 210°F to provide an excellent diesel fuel having a viscosity at 210°F of 70 S.U.S. (Refer to enclosed Chart 1.)

The additive package in most diesel and automotive engine oils contains varying amounts of inorganic material, which will produce ash upon combustion; this, plus fuel carbon residue, wear metals, airborne contaminates, and other extrinsics found in used lubricating oil could result in heavy ash build-up in the combustion zone of an engine, as well as adding materially to the load on the engine lubricating oil.

MOUNT VERNON, OHIO 43050 • PHONE 614/397-0121

If it were intended that an engine was to burn a fairly large volume of waste lube oil, it is my opinion the waste oil should be centrifuged and clay filtered to remove as much of the ash forming material as possible. Centrifugation would remove most suspended materials and prolong the life of the active clay, whose primary purpose is to reduce the additive content of the waste oil.

Your letter indicated the primary concern of the project was that the "fuel oil will not significantly impair engine performance or shorten the life expectancy of the engine". In order to meet that primary objective, I feel the prepared fuel, however treated, should not exceed an ash content of 0.02% by wt., with a total sulfur content of not over 1.0% by wt.

I assume you are aware of the many diesel engines, world-wide, which are burning various grades of residual oil or crude oil as fuel; the problems you will encounter in the preparation of waste lubricating oil for fuel will be very similar, though your final product will be much the superior fuel.

Sincerely,

D. L. Siekkinen
Chemist
Materials Laboratory

/n

w/attachment

CUMMINS ENGINE COMPANY, INC.

COLUMBUS, INDIANA 47201

CUMMINS

TELEPHONE | AREA CODE 812 372-7211

5 June 1974

U. S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge, Massachusetts 02142

Attention: James Sabo, Cadit l/c
USCG Academy

Gentlemen:

This refers to your request for information dated 31 May 1974 regarding utilization of waste lubricating oil as a fuel for diesel engines. Cummins Engine Company, Inc. has done considerable research into this technique and have developed a paper on the subject.

We enclose a copy of Service/Parts Topic No. 74T 5-6, File Group 5, dated May, 1974. We believe this will answer the questions you have on the subject. Should you desire additional information, please let us know.

Very truly yours,

C. D. Shrake/sd

Manager - Defense Products

Enclosure - SEE APPENDIX C OF THIS REPORT.

372-6415

Detroit Diesel Allison
Division of General Motors Corporation

General Offices
13400 West Outer Drive
Detroit, Michigan 48228
Phone: (313) 592-5000

August 8, 1974

U. S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge, Mass. 02142

Attention: Dr. John R. Hobbs

Gentlemen:

This is further to our recent telephone conversation and my letter of June 27 to Cadet 1/c James Sabo concerning the adverse results which may be expected as a result of burning waste lube oil in Detroit Diesel Engines.

In our conversation you indicated that the percent by volume of lube oil to Diesel fuel would not exceed 1.0% and would more likely be somewhat less in most circumstances.

After further discussion with our Mr. Brandes by both yourself and the writer, he would expect that the results of the practice at the reduced proportions indicated would have the effect of a proportional reduction in the adverse effect.

Please recognize that it is not our intent to prohibit you from an effort to solve the very pressing problem of waste disposal faced by ocean going vessels and the U. S. Coast Guard in particular who certainly must set perhaps the best example. We do feel, however, that it is our obligation to you as a satisfied user of Detroit Diesel Allison products to caution on the results of a practic which will, from our experience, contribute, to somewhat reduced engine life. What that reduction before overhaul will be will depend on the amount of lube oil ingested. The constituents of a good lubricating oil are such that under the high temperatures to which they are subjected in the combustion chamber cracking takes place which transforms many of these from a liquid directly to an ash deposit.

If the practice which you contemplate is implemented, we would suggest that the proportion of lube oil to fuel oil be kept to a minimum so as to reduce the effect anticipated.

Very truly yours,

C. W. Hartel, Asst. Mgr.
Government Sales

bc
cc: J. Brandes

DETROIT DIESEL's POSITION ON MIXING DRAINED LUBE IN DIESEL FUEL FOR BURNING IN DETROIT DIESEL ENGINES

Summary

Detroit Diesel does not recommend or support mixing any drained lube oil in diesel fuel. The owner/operator does so at his own risk. Detroit Diesel will not be responsible for any detrimental effects which it determines resulted from this practice.

Discussion

Detroit Diesel Fuel and Lubricant Specifications are published in Form 7SE-270 (Rev. 12/73). The fuel selected should be completely distilled material. That is, the fuel should manifest at least 98% by volume recovery when subjected to A.S.T.M. Distillation designated as method D-86. Fuels marketed to meet Federal Specification VV-F-800 (grades DF-1 and DF-2) and A.S.T.M. Designation D-975 (grades 1-D and 2-D) meet the completely distilled criteria.

Detroit Diesel designs, develops, and manufactures most of its diesel engines to operate on these clean burning fuels. It should be noted that the ash content of these fuels is usually somewhere between 0.005 to 0.01% by weight.

The practice of adding any ash containing ingredients (e.g. waste or drained lube oil) is not supported and Detroit Diesel will not be responsible for any detrimental effects which it determines resulted from the use of such ingredients in the diesel fuel.

Effects of High Ash in Diesel Fuel

The burning rate of diesel fuel exceeds the burning rate of diesel crankcase oil by hundreds of times. Detroit Diesel has specified ash limits for crankcase oil since 1969 in order to control the deposits that tend to form in the combustion chamber. The presence of excessive deposits, especially ash, usually results in guttered exhaust valves and/or stuck piston rings. For this reason, it would not be rational to add ash containing lube oil portions to the diesel fuel.

Effects of Ash Content in Lube Oil

As previously indicated, Detroit Diesel has imposed ash limits for crankcase oils since 1969. Figures 1, 2, and 3 attached show the deposit levels experienced when a lubricating oil having a 2.2% by weight sulfated ash content was subjected to a 531 hour laboratory dynamometer engine test cycle. Figures 4, 5, and 6 show the deposit levels obtained when a lubricating oil having a 1.0% by weight sulfated ash content was subjected to the same

cycle for 531 hours. Figures 7, 8, and 9 show the relatively light deposits produced when a commercial ashless oil was subjected to the same cycle for the same number of hours. These photographs clearly illustrate the differences in deposit levels obtained from lubricating oils having a broad range of ash content. The ash forming tendencies would be greater if the ash containing ingredients were present in the diesel fuel.

Engine Operation - Hypothetical Case

The ash forming tendencies of a diesel fuel (containing some drained lube oil) compared to that of a crankcase oil can be further demonstrated in the following example. Table 1 attached describes the hypothetical operating conditions of a diesel powered highway truck. The fuel and oil economy, ash content of the crankcase oil, and the amount of drained lube oil in the diesel fuel are all indicated. Table 2 shows the quantities of diesel fuel and lube oil consumed after 100,000 miles of operation. The quantities of potential ash derived from the crankcase oil and diesel fuel (contaminated with drained lube oil) are also indicated. Detroit Diesel's recommendations of lubricants with ash limits are based on experience in numerous service applications. It would be irrational to consider the use of drained lube oil in diesel fuel.

J. G. Brandes
June 5, 1974

ENGINE OPERATION - HYPOTHETICAL CASE

Engine Road Speed, M.P.H.	40
Fuel Economy, M.P.G.	4
Lube Oil Economy, M.P.Q.	300
Ash Content of Lube Oil, Wt.%	1
Amount of Drained Lube in Diesel Fuel, Vol. %	5

TABLE 1

FLUIDS CONSUMED AND POTENTIAL ASH FORMED

AFTER 100,000 MILES OPERATION

Gals. Lube Oil Burned	84
Lbs. Lube Oil Burned	622
Lbs. Lube Ash Produced from Crankcase Oil	6.2
Gals. Fuel Burned	25,000
Lbs. Fuel Burned	175,000
Lbs. Ash Produced from Lube Oil in Diesel Fuel	92.5

TABLE 2

GENERAL ELECTRIC

GAS TURBINE
PRODUCTS DIVISION

TECHNICAL RESOURCES
OPERATION

GENERAL ELECTRIC COMPANY, ONE RIVER ROAD, SCHENECTADY, NEW YORK 12345
Phone (518) 374-2211

August 6, 1974

Subject: Burning Diesel Lube Oil Diluted with Distillate
Fuel in a Gas Turbine

Mr. John Hobbs
Code 641
Transportation Systems Center
U.S. Dept. of Transportation
Kendall Square
Cambridge, Mass. 02142

Dear John:

Following up our telephone conversation on August 2 on burning dilute solutions of diesel lube oil in diesel fuel, I have enclosed a copy of the General Electric gas turbine fuel brochure which includes our fuel specification for industrial heavy duty turbines.

I have also enclosed copies of two papers from the ASTM Manual STP531 on Requirements, Handling and Quality Control of Gas Turbine Fuel. These two papers are concerned with distillate fuel application in aircraft-derivative type turbines. The Winkler paper on Management of Gas Turbine Fuel Systems might be pertinent to your proposed fuel application. Specific information on the effect of the contaminant mix and levels might be obtained by calling the author, M. Winkler, at A/C 203, 677-4081, Ext. 458.

Sodium, potassium, lead and vanadium are the contaminants which can cause hot corrosion; the vanadium apparently not being a problem in your application. On-board fuel clean up should remove at least part of the sodium and potassium, and dilution with a very low sodium distillate fuel could reduce the levels at the turbine so that the fuel could be within specification limits.

Calcium concentration is limited to prevent combustion ash deposit buildup in the hot gas path which would require periodic turbine cleaning.

Barium is used in trace quantities in some gas turbine fuels to reduce smoke emissions. High levels of barium could result in combustion ash buildup in the hot gas path and in time, reduce turbine output and efficiency.

If you have any further questions, please feel free to call.

Very truly yours,

J. W. Hickey Jr.

J. W. Hickey, Engineer
Fuels & Corrosion
Bldg. 53 - Room 311
Extension 5-9711

js
enclosures

cc H. Doering
N. Dibeltus

INTERNATIONAL HARVESTER COMPANY

CONSTRUCTION EQUIPMENT DIVISION

MELROSE PARK WORKS
10400 WEST NORTH AVENUE • MELROSE PARK, ILLINOIS 60160

TELEPHONE—AREA CODE 312
FI 3-1800
FROM CHICAGO—ES 8-4100

August 12, 1974

Dr. J. R. Hobbs
Code 641
Transportation Systems Center
U.S. Department of Transportation
Kendall Square
Cambridge, Massachusetts 02142

Dear Dr. Hobbs:

Reference is made to our conversation of 8-8-74 on disposal of used engine oil.

As requested, attached is a copy of our Service Bulletin #01-74-01. The maximum recommended crankcase oil addition to fuel is 6½%.

If we can be of further service, please let us know.

Very truly yours,

J. M. Gottlieb

cc: J. P. Horne

n

BULLETIN PARTS AND SERVICE

February 1, 1974
BPOS-11
HBPOS-2
(NE)

NO: 01-74-01 (CU)
GROUP: General
MODEL: All CE Machines with IH Diesel Engines

Subject: Disposal of Used Engine Oil
(Reference: 1. Product Information Letter (P.I.) 01-73-03
2. Ads in National Construction Magazines)

Disposal of used engine oil by adding it to the fuel in the vehicles tank is approved for all International Harvester diesel engines.

At time of the drain period, it is permissible to add the used lube oil directly to the fuel tank of the unit in question. (See Item 5, under Caution Section for exceptions).

PROCEDURE

1. Collect engine oil drained from oil pan and filters in a clean container.
2. Add only the oil drained from the vehicle to the fuel tank through a fine mesh screen funnel.
3. Fill balance of fuel tank with fuel.
4. Add used oil to tank only at regular oil drain periods.

CAUTION:

1. Containers and funnels, etc., should be clean, contamination will have an adverse effect on fuel filter life and may damage injection equipment. The used engine oil does not affect filter life.
2. Oil should not be added to the fuel tank when it is anticipated that engines will be shut-down for a period longer than one month.
3. When engines are operating at light loads, the use of engine oil in the fuel may cause a slight increase in smoke level. Normally, this is temporary and the smoke level will come back to normal after working machine "hard" for a few hours.

2.

4. If abnormally high smoke level should occur on older machines after prolonged light load operation or after excessive amount of oil has been used in the fuel, the injection nozzle tips should be cleaned externally by brushing off soft carbon build-up. It is not necessary to disassemble the nozzles.

5. Presently, the PH-140 PAYhauler, 250C and 175C Loaders, due to a smaller fuel tank capacity, have a greater drain amount than the 6-1/2% ratio. If owner desires, on these three units, oil drain overage can be held for next fuel tank refilling.

   (Procedure is based on a maximum fuel tank add amount of 6-1/2% crankcase oil).

   This is a current ad as it appears in the Construction Magazines.

Turn your used engine oil into fuel!

Here's help for the fuel shortage. When you change crankcase oil, you can reuse it as fuel in the same machine.

But, please follow these guides:

1. Approved for International diesel engines only.
2. Do not use more than a 6½% ratio of used oil to fuel.
3. Always pour used oil back into the same machine.
4. Drain oil from pan and filters into *clean* containers.
5. Use a fine mesh screen funnel to filter the used oil when adding it to the fuel tank.

Saving fuel and money is good business these days. Call your International Harvester Distributor for complete information on reusing used crankcase oil for fuel without harming engines or injectors.

CONSTRUCTION EQUIPMENT
MELROSE PARK, ILLINOIS

gr

Technical Publications Department
Construction Equipment Division
International Harvester Company

APPENDIX C

FILTER INFORMATION

Service/Parts Topics

May, 1974

No. 74T 5-6

File Group 5

Ref: (A)

Burning Used Lubricating Oil With Fuel Oil (All Engine Models)

Due to increased fuel costs and the lack of adequate means to dispose of used lubricants a method has been recognized to dispose of used lubricants by mixing with fuel. Cummins Engine Co., Inc., has monitored fleets following this procedure and has conducted some laboratory tests to determine the effects of mixing used lube oil with fuel. This Service Bulletin contains a summary of the test results, and guidelines for pre-mixing and filtering used crankcase oil for use with fuel should a customer or fleet elect to use this method of disposal. Although no detrimental effects on the engine or components have been noticed, Cummins Engine Company does not accept any responsibility for failures or adverse effects, resulting from burning used lube oil in the fuel. The logic being that Cummins Engine Company has no control over the volume of used lube oil added nor do we have control of filtration method used.

Engine Performance

During testing there was no noticeable difference in performance and fuel consumption was not affected.

Engine Component Test Results

Engine components were examined after 100,000 miles of operation, oil deposits and carbon build-up were considered typical, and only normal wear was found on moving engine parts. Conclusions are that there is no detrimental effects on engine components from using this procedure.

Fuel System

Wear on fuel pump components and injectors after 100,000 miles of operation appeared to be typical.

Carbon build-up on injector plungers was normal and no signs of erosion were found on injector cup spray holes.

There was an insignificant effect on fuel filter element life when using this procedure.

Emission Test

Assuming that clean used crankcase oil performs like new lube oil, emission tests were performed using a mixture of new lubricating oil at up to 10% by volume with No. 2 diesel fuel. These tests were run on two (2) engines, with the following results.

1. A 30 to 40% reduction in acceleration and lug down smoke occurred with a 5% lubricating oil mixture on naturally aspirated engines. See Fig. 1.

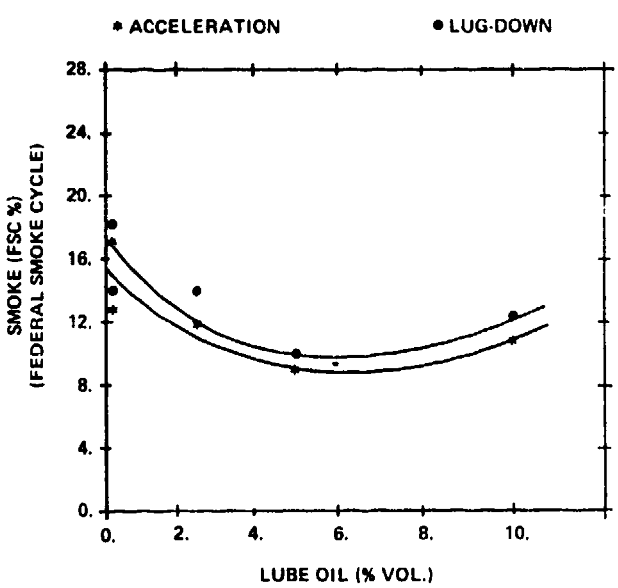

Fig. 1. Accelleration and Lug-Down Smoke

2. There was no appreciable difference in smoke level with turbocharged engines.

3. A slight reduction in BSCO (Brake Specific Carbon Monoxide).

4. There is an insignificant increase in BSHC (Brake Specific Hydrocarbons) with the lube oil mixtures up to 5%.

5. No significant change in $BSNO_2$ (Brake Specific Oxides of Nitrogen).

Cummins Cummins Engine Company, Inc., Columbus, Indiana U.S.A. 47201
Cummins Engine Company, Ltd., Darlington, Co. Durham, England DL1-4PW

Registered Office: Coombe House, St. George's Square, New Malden, Surrey KT3 4HO Registration No. 573951 England

Various concentrations of 30W lubricating oil were pre-mixed with No. 2 diesel fuel during testing.

It was found that using 5% by volume concentration reduced smoke 30-40% during acceleration and lug down on naturally aspirated engines. Long-term effects on combustion efficiency cannot be predicted from laboratory tests that were made.

The use of used lubricating oil with fuel may increase PNA's (Polynuclear Aromatics) and metallic oxide emissions; however, the effect of these are unknown at this time.

Guidelines

The following guidelines should be followed when disposing of used lubricating oil by pre-mixing and using it with diesel fuel.

1. A maximum addition of 5% used lubricating oil is recommended.

2. The lubricating oil must be pre-mixed one part lubricating oil to three parts of fuel prior to filtering.

3. Used lubricating oil/fuel mixture must be filtered thru a Fleetguard LF750 by pass filter or equivalent.

4. Filtration media must remove water and sludge from used lubricating oil/fuel mixture.

The following is a list of Do's and Don'ts that must be followed if the procedure of mixing used lubricating oil with fuel is adapted.

Do follow guide lines listed above.

Do use crankcase oil from Cummins Diesel Engines only.

Do keep containers and storage tanks clean.

Do change fuel filter elements at prescribed intervals.

Do Not mix used lube oil from gasoline engines with diesel fuel.

Do Not mix cleaning solvents or lubricating oil diluted with cleaning solvents with diesel fuel.

Do Not mix transmission or hydraulic oils with diesel fuel.

Do Not mix used lubricating oil with diesel fuel if evidence of coolant leakage into crankcase is present.

Do Not mix used lubricating oil from a failed engine (due to contaminant level) with the fuel.

Filter Mixer

A portable pump and filtration system has been developed, it is designed to pump used lubricating oil from the crankcase and fuel from the vehicle fuel tank at a ratio of one (1) Part oil to three (3) parts of fuel, then mix the two via a mixing unit, pump the fuel mixture through a filtration unit (made up of three (3) Filter Elements) then into fuel tank. See Fig. 2.*

The material required to assemble the filter mixer unit should be available locally. Table 1, includes manufacturers part number (where applicable) and where purchased. Orificing of pump BBV-2 used for crankcase oil may be accomplished by reducing the 90 deg. Flexible Hose fitting on discharge side of pump to 3/8" inside diameter.

Filter Mixer Operation

1. Install No. 8 Flexible Hose fitting (1/2" NPT) into oil pan drain plug. Using No. 8 Flexible Hose connect oil pan sump drain fitting to male end of quick disconnect coupling, attach quick disconnect coupling to frame or engine above pan level.

2. At time of lubricating oil change couple suction side of centrifugal pump to quick coupling at frame. See Fig. 3.

3. Position hose connected to pump below fuel level in vehicle fuel tank.

4. Place hose from filtration unit into fuel tank.

The lubricating oil and fuel is mixed by passing through a three (3) element filtration unit. The fuel mixture is then returned to the fuel tanks.

*Patent pending. This system may be used for the servicing of Cummins' engines only.

Table 1: PARTS LIST – FUEL/OIL BLENDER

Fig. 2 Ref. No.		Qty.	Item
1	*	2	BBV-2 Centrifugal Pumps
2	**	1	1/2 H.P. 1750 RPM Double Shaft Motor
3		2	50 PSI Gauges
4	***	1	3036-3 Filter Assembly
4A	***	2	890 Wall Brackets (Used To Mount Steel Plate To Filter Assembly)
	†		LF-750 Filter Elements (Spares)
5		2	Flexible Couplings
6	****	1	3/4 – 10 – 322 – 5 Mixer
6A		1	1/4" x 14" x 37" Steel Plate (Used To Mount Motors, Etc. On Filters)
7		7	No. 8 x 1/2" x 90 Deg. Flexible Hose Fittings
8		9	No. 8 Flexible Hose Swivels
9		3	1/2" Pipe Tee
10		3	No. 8 x 1/2" N.P. Straight Flexible Hose Fitting
11		2	3/4" x 1/2" Pipe Reducers
12		2	3/4" x 14" Reducing Bushings
13		6	1/2" Close Nipples
14		50 Ft.	No. 8 Flexible Hose
15		1	3/8" Orifice Elbow – (Lubricating Oil Pump Discharge)
16		2	90 Deg. Street "L" 1/2" NPT

* **BBV-2 Pumps Douglas Inc. 2530 Bluff Road Indianapolis, Indiana**

*** **890 – Wall Brkts. 3036 – 3 Filter Assy. Purchase From Lubrifiner Dealer**

** **1/2 H.P. Motor SS-34061 Marathon Electric Wausau, Wisconsin**

**** **322 – 5 Mixer Kenics Corp. 1 Southside Drive Danvers, Mass.**

† **LF-750 Filter Elements Purchased From Local Cummins or Fleetguard Dealer**

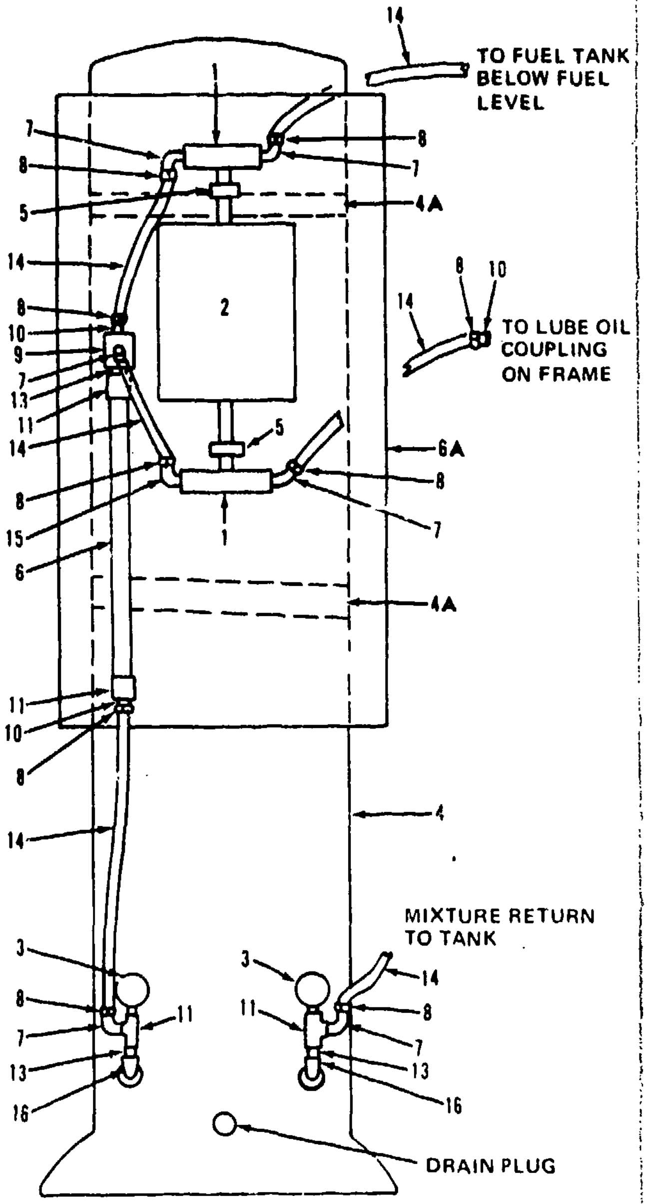

Fig. 2. Filter Mixer Assembly Diagram

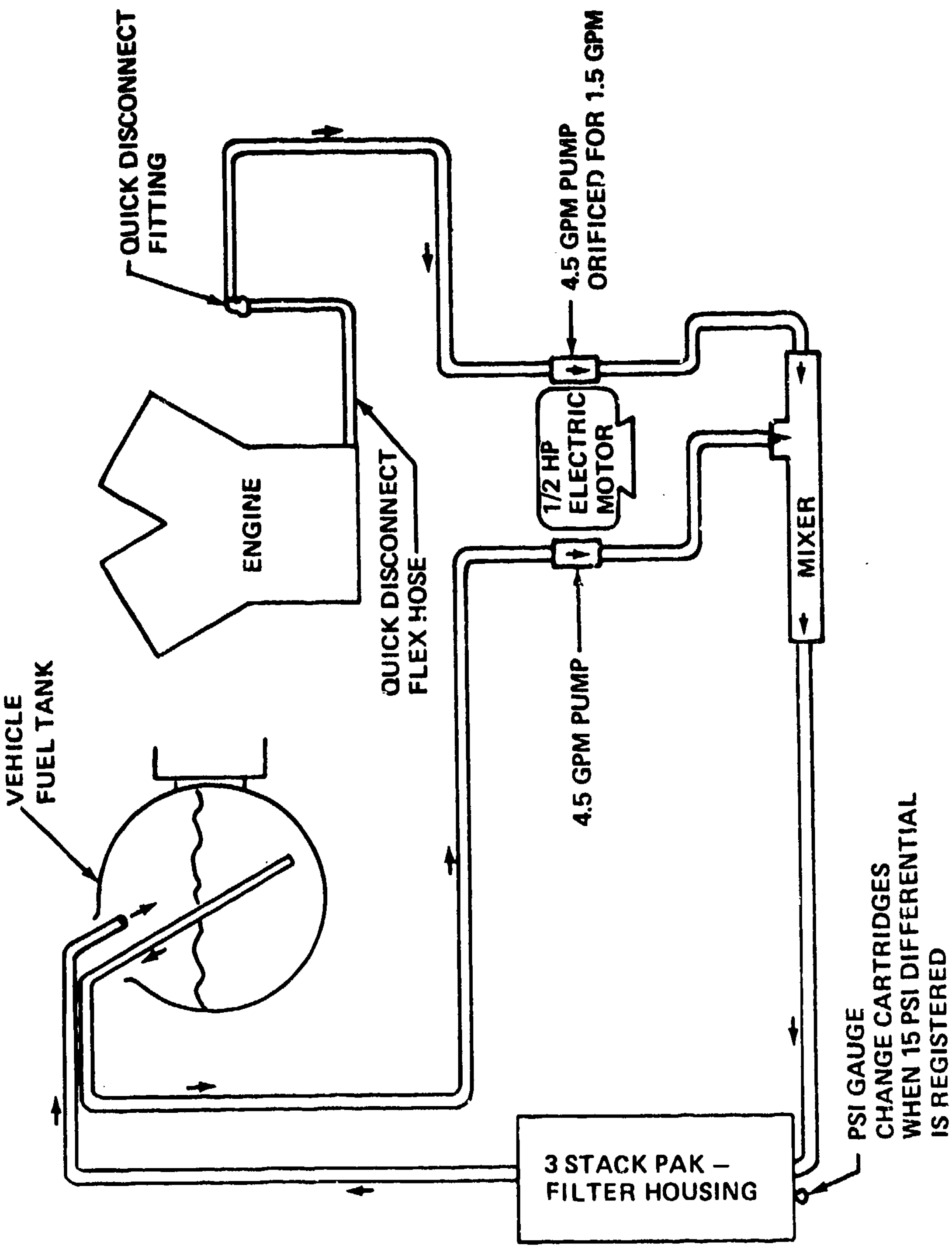

Fig. 3. Filter Mixer Schematic

APPENDIX D

EMISSIONS DATA

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United States Department of the Interior
BUREAU OF MINES
BARTLESVILLE ENERGY RESEARCH CENTER
P. O. BOX 1398
BARTLESVILLE, OKLAHOMA 74003

August 6, 1974

Dr. John Hobbs
DOT-TSC
Kendall Square
Code 641
Cambridge, MA 02142

Dear John:

Enclosed are the data we obtained for the lube oil-diesel fuel tests. The engine used in these tests is a Caterpillar D333-C, precombustion-chamber, naturally-aspirated engine. The 11-mode average data are identical to EPA's 13-mode cycle averages.

The addition of the lube oil (1% lube-99% diesel) appeared to have no significant effect on emissions with the possible exception of unburned hydrocarbons. However, even here the only difference was at the idle condition. We have noted that the level of unburned hydrocarbon produced by this engine at the idle condition is highly variable (10 to 100 grams per hour). Thus, we conclude that the lube oil had no significant effect on emissions.

If you have any questions about the data, please feel free to call at any time.

Sincerely,

Bill Marshall

William F. Marshall
Project Leader
Fuels Combustion Research

Enclosure

FTP-HEAVY DUTY DIESEL WITH OIL

DATE 7 31 74 TEST NO. 1

BARO. PRESS. 743.5
REL. HUM. 38
TEMPERATURE 92
MATRIX FACTOR 9.26

H (G/LB) 86.9
K NOX 1.0306
NO. OF MODES 11

SPEED	POWER	FUEL	CO	HC	NOX	SMOKE
1400	0.0	8.6	147.8	36.1	31.6	2.0
1400	28.7	16.3	78.8	20.6	146.5	1.0
1400	57.5	24.8	45.7	20.5	286.7	1.0
1400	86.7	35.2	38.8	20.4	312.2	1.5
1400	109.5	48.3	138.9	18.5	267.4	5.0
600	0.0	2.4	46.9	10.1	10.5	1.0
2200	0.0	17.8	197.1	35.6	80.6	2.5
2200	34.9	26.8	121.4	37.4	172.9	2.0
2200	69.9	37.4	72.6	31.4	347.0	1.5
2200	105.1	49.4	57.1	29.9	517.1	1.5
2200	138.0	64.8	75.9	27.6	541.1	1.5

11 MODE AVERAGES
POWER 50.42
BSFC .5322
BSCO 1.73
BSHC .48
BSNOX 4.33
SMOKE 1.8

FTP-HEAVY DUTY DIESEL WITHOUT OIL

DATE 8 1 74 TEST NO. 2

BARO. PRESS. 744.5
REL. HUM. 38
TEMPERATURE 92
MATRIX FACTOR 9.26

H (G/LB) 86.7
K NOX 1.0302
NO. OF MODES 11

SPEED	POWER	FUEL	CO	HC	NOX	SMOKE
1400	0.0	8.4	135.6	42.9	37.2	2.0
1400	28.6	16.1	69.0	35.4	143.9	1.5
1400	57.4	23.9	40.8	34.3	301.4	1.0
1400	86.6	34.9	38.3	31.1	334.1	1.5
1400	112.4	48.9	110.6	22.9	280.8	6.0
600	0.0	2.7	73.9	76.2	11.9	1.5
2200	0.0	17.8	176.9	41.9	102.9	4.0
2200	34.7	26.6	112.3	35.5	190.0	3.0
2200	70.0	37.3	73.4	31.3	360.5	2.0
2200	104.7	48.9	62.4	25.7	518.3	2.0
2200	139.5	65.6	78.4	19.2	547.0	2.5

11 MODE AVERAGES
POWER 50.71
BSFC .5287
BSCO 1.71
BSHC .81
BSNOX 4.49
SMOKE 2.3

FTP-HEAVY DUTY DIESEL WITH OIL

DATE 8 S 74 TEST NO. 3

BARO. PRESS. 743.0
REL. HUM. 32
TEMPERATURE 88
MATRIX FACTOR 9.26

H (G/LB) 64.2
K NOX .9738
NO. OF MODES 11

SPEED	POWER	FUEL	CO	HC	NOX	SMOKE
1400	0.0	8.2	138.7	29.4	35.3	3.0
1400	28.5	16.4	70.7	22.2	151.3	2.0
1400	57.4	24.2	41.7	25.0	314.0	3.0
1400	86.0	34.6	38.6	16.8	330.5	3.0
1400	113.7	49.4	185.5	13.8	263.5	9.0
600	0.0	2.7	50.8	11.2	12.3	3.0
2200	0.0	18.1	56.9	32.8	26.1	5.0
2200	34.7	24.7	122.8	29.5	181.2	4.0
2200	69.1	37.2	91.9	25.2	357.8	3.0
2200	104.2	49.1	70.1	20.1	513.8	3.0
2200	140.3	63.9	84.6	15.3	532.4	3.0

11 MODE AVERAGES
POWER 50.72
BSFC .5245
BSCO 1.62
BSHC .41
BSNOX 4.32
SMOKE 3.6